This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

LITTAUER LIBRARY
LI 2X1Q F.

HARVARD UNIVERSITY
MAY 27 1940
GRADUATE SCHOOL
OF PUBLIC ADMINISTRATION

E3-23

F. E. Winsor,
Nov. 3, 1899.

FRANK E. WINSOR.

HARVARD UNIVERSITY
MAY 27 1940
GRADUATE SCHOOL
OF PUBLIC ADMINISTRATION

REPORT

OF THE

FILTRATION COMMISSION

OF THE

CITY OF PITTSBURGH,

PENNSYLVANIA,

JANUARY, 1899.

C. C. No. 406.

WHEREAS, Recent advancement in sanitation is in the direction of agitation for the filtration of public water supplies to remove the pollution, which comes from the increase of population along the banks of the supplying streams; and,

WHEREAS, Investigations and experiments in this direction, while limited in practical operations to but one city in this country, have, nevertheless, progressed far enough to command the careful consideration of a progressive city such as Pittsburgh; therefore,

Resolved, That a commission be created, of which the Mayor of the city and the Presidents of the Councils and eight representative citizens and tax payers to be appointed by the Mayor shall be members, at least two of whom shall be physicians of recognized standing:

Resolved further, That it shall be the duty of this commission to thoroughly investigate as to the character of our present water supply in its relation to public health, the effect of sand filtration and the advisability of establishing a sand filtration plant for the city of Pittsburgh, with an estimate of the cost of establishing and maintaining the same; and also to investigate the feasibility and advisability of seeking other sources of supply. And the commission shall report its findings and recommendations together with such evidence as may be useful for the guidance of these Councils in acting prudently and for the best public interest in this matter.

In Councils, June 8, 1896; Rule suspended, read three times and finally passed.

ATTEST:
E. J. MARTIN,
Clerk of Select Council.

Mayor's Office, June 10, 1896.

APPROVED:
H. P. FORD,
Mayor.

ATTEST:
GEO. H. WELSHONS,
Mayor's Clerk.

TABLE OF CONTENTS.

PAGE.

Resolution,. iii
Table of Contents,..... v

Report of Filtration Commission:—

Scope of Investigations and Organization, ... 1
Character of the Present Water Supply in Relation to Public Health, ... 3
Effect of Sand Filtration, ... 3
Advisability of Establishing a Sand Filtration Plant,..... 4
Cost of Establishing and Maintaining a System of Sand Filtration,..... 6
Feasibility and Advisability of Seeking Other Sources of Supply,..... 6
Conclusion, ... 7

Report upon the Sources of Typhoid Fever in Pittsburgh, by Prof. Wm. T. Sedgwick:—

Introduction, ... 11
The Sources of Typhoid Fever in Cities,—
Atmospheric Dust,. 12
Infected Uncooked Food,..... 12
Secondary Infection or Contagion, ... 13
Ice Supply,..... 14
Milk Supply,..... 14
Public Water Supply, ... 14
The Water Supply Derived from the Monongahela River,..... 15
The Water Supply Derived from the Allegheny River,..... 16
The Allegheny River is a Rapid Stream with little or no Opportunity for Self-Purification, 18
Distribution of Typhoid Fever in Pittsburgh,..... 22
The Allegheny River not the only Polluted Water Supply of Pittsburgh,..... 23
Summary and Conclusion,..... 23

Report of the Consulting Engineer, Allen Hazen, C. E.:—

Introduction, ... 27
Sanitary Condition of the Present Water Supply, Drawn from the Allegheny River,.... 30
Sanitary Condition of the Water Supplied to the South Side from the Monongahela River, 32
Average Composition of Allegheny and Monongahela River Waters,..... 33
Muddiness,..... 34
Nature of Filtration,..... 36
Experiments upon Filtration,..... 37
Results from Experimental Filters,—
Summary of Results from Sand Filters by Months,..... 39
Composition of Allegheny River Water before and after Settling, and after Passing through Sand Filters,..... 39
Summary of Results from Mechanical Filters by Months,..... 40.
Composition of Allegheny River before and after Passing Mechanical and Sand Filters,..... 43
Results with Sand Filters,—
Necessity of Preliminary Sedimentation,..... 44
Necessity of Covering Filters,..... 44
Effect of Mud, Crude Petroleum, Mine Waste, etc.,..... 45
Frequency of Scraping,.. 47

PAGE.

Results with Mechanical Filters,—
Wasting Effluent after Washing,... 49
Influence of Amount of Sulphate of Alumina on Bacterial Efficiency,... 50
Influence of Degree of Turbidity upon Bacterial Efficiency,... 52
Influence of Number of Bacteria in Raw Water upon Bacterial Efficiency,... 54
Average Results Obtained with various Quantities of Sulphate of Alumina,... 54
Amount of Sulphate of Alumina Required to Clarify Turbid Waters,... 55
Amount of Sulphate of Alumina which must be Used,... 55
Action of Sulphate of Alumina and the Quantity of Sulphate of Alumina which can be safely Used,... 56
Comparison of the Qualities of Effluents Obtained by Sand and Mechanical Filtration,—
Bacterial Efficiency,... 60
Clearness of Effluent,... 61
Color,... 62
Hardness,... 62
Boiler Tests,... 63
Cost of Construction of Filters,... 64
Cost of Maintenance,... 66
Final Comparison, Sand and Mechanical Filters,... 68
Necessity of a Storage Reservoir for Raw Water,... 68
Other Methods of Filtration Considered,... 69
Auxiliary Supply of Unfiltered Water for Manufacturing Purposes,... 71
Amount of Water to be Provided and the Restriction of Waste,... 73
Cities which have Adopted the Meter System,... 76
Equitable Basis for Meter Rates,... 77
Cost of Installing Meter System,... 78
Supply of the South Side with Filtered Water,... 79
Gravity Sources:—
Indian Creek,... 81
Chief Features of the Project,... 81
Quantity of Water,... 81
Quality of Water,... 82
Difficulties with Coal Lands,... 82
Cost of Work,... 82
Comparison of the Cost of a Gravity Supply and the Present Supply Filtered,... 82
Comparison of Costs Tabulated,... 84
Conclusions and Recommendations,... 85

Report upon a Gravity Water Supply from Indian Creek, by Emil Kuichling, C. E.:—
Source,... 89
Available Quantity,... 91
Consumption,... 94
Storage Reservoir and Dam,... 96
Tunnel Conduit,... 98
Steel Pipe Conduits,... 99
Intermediate Structures on Pipe Conduits,... 101
Estimated Cost,... 102
Operating Expenses and Maintenance,... 103
Conclusion,... 105

Report of the Resident Engineer, Morris Knowles, C. E.; Chapter I,—General Outline of the Work:—
Organization,... 109
Sand Filters,... 110
Mechanical Filters,... 110
Worms Tile Filter,... 111
Berkefeld Filter,... 112

PAGE.
Surveys,... 112
Gravity Supply,... 113
Miscellaneous Studies,... 113
Pollution Investigations,... 114
Experimental Filter Plant,... 114
Boiler Experiments,... 115
Asbestos,... 115
General,... 115
Title of Chapters and Appendices,... 117

Chapter II,—Sand Filter Experiments:—
Description,... 117
Operations,... 119
Cracks in Filter Walls,... 120
Methods,... 120
Analyses of Sand,... 121
Dissolved Oxygen,... 123
Bacterial Efficiency after Scraping,... 124
Tabulation of Results by Months,... 126

Chapter III,—Warren Filter Experiments:—
Description,... 155
Settling Basin,... 155
Coagulant,... 156
Filter,... 156
Washing,... 157
Agitator,... 158
General,... 158
Operations,... 159
Composition of Coagulant,... 159
Variations in the Rate of Filtration and in the Application of Coagulant,... 160
Bacterial Efficiency after Washing,... 166
Special Experiment to Show the Effect of Using different Quantities of Coagulant,... 169
Tabulation of Results by Months,... 171

Chapter IV,—Jewell Filter Experiments:—
Description,... 180
Settling Basin,... 180
Coagulant,... 180
Filter,... 180
Washing,... 181
Agitator,... 182
Operations,... 182
Sand Used,... 183
Variations in the Rate of Filtration and in the Application of Coagulant,... 183
Bacterial Efficiency after Washing,... 187
Mechanical Effect of Trailing,... 189
Bacterial Efficiency after Trailing,... 190
Effect of Cleansing with Soda Ash,... 191
Special Experiments to Show the Effect of Using different Quantities of Coagulant,... 191
Tabulation of Results by Months,... 193

Chapter V,—Worms Tile Filter Experiments:—
Description,... 202
Coagulating Solution and Apparatus,... 202
Scrubbers,... 202
Filter Tanks and Tiles,... 203
Washing,... 203
Operations,... 204

PAGE.
Breakage of Tiles,... 204
Bacterial Efficiency after Washing,... 205
Tabulation of Results by Months,... 206

Chapter VI,—Boiler Experiments:—
Description,... 216
Tabular Statement of Dimensions,... 216
Formation of Scale,... 217
Conclusion,... 219

Appendix No. 1, Methods of Chemical Analyses and Discussion of Results, by Dr. Walther Riddle; Part I, Methods:—
Collection of Samples and Preliminary Examination,... 225
Turbidity and Sediment,... 225
Color,... 225
Nitrogen as Ammonia,... 226
Nitrogen as Nitrites,... 227
Nitrogen as Nitrates,... 228
Chlorine,... 228
Residue on Evaporation,... 229
Loss on Ignition,... 229
Hardness,... 230
Alkalinity,... 230
Sulphuric Acid,... 230
Iron,... 231
Alumina,... 231
Dissolved Oxygen,... 232
Part II,—Discussion,... 232

Appendix No. 2, Description of Sources of Samples and Results of Chemical Analyses, also Number of Bacteria Per Cubic Centimeter:—
Introduction,... 237
Allegheny River at Brilliant,... 237
Pittsburgh City Tap,... 244
Gate Chamber,... 246
Settling Basin,... 250
Effluents—Sand Filters,... 253
Effluent—Warren Filter,... 260
Effluent—Jewell Filter,... 262
Applied Water—Worms Tile Filter,... 265
Settled Water— " " " ... 266
Effluents— " " " ... 268
Monongahela River,—at Intake of Monongahela Water Company,... 270
South Side Tap,... 275
Allegheny River at Montrose,... 278
Effluent—Montrose Crib,... 280
Allegheny City Tap,... 282
Allegheny River at Hulton,... 285
Effluent—Hulton Crib,... 287
Verona Tap,... 289
Allegheny River at Wildwood,... 292
Effluent—Wildwood Crib,... 294
Wilkinsburg Tap,... 296
Effluent—Sharpsburg Crib,... 298
Allegheny River at Etna,... 299
Effluent—Etna Crib,... 301
Etna Tap,... 304
Allegheny River at Millvale,... 305

PAGE.
Effluent—Bennett Water Company Crib, Millvale,..... 306
Millvale Tap,..... 309
Ohio River at Sewickley,.. 310
Effluent—Sewickley Crib,..... 311
Sewickley Tap,..... 311
Tap in Department of Public Safety Building, before Filtration,..... 312
Tap in Department of Public Safety Building, after Filtration,..... 313
Water in Experimental Boilers,..... 314
Driven Well at Brilliant, ... 316
Howe Spring,..... 316
Well at McConway-Torley Manufacturing Company,..... 317
Well at Sligo Mills,..... 318
Miscellaneous City Samples,..... 318
Miscellaneous Suburban Samples,..... 320
Indian Creek and Vicinity,..... 321

Appendix No. 3, Bacteriological Investigation of Fifteen Samples of Pittsburgh City Water, by Eugene Wasdin, M. D.:—.. 327
Tabulation of Results,..... 330

Appendix No. 4, Report upon Bacteriological Investigations, by Wm. R. Copeland:—
Introduction,..... 333
Part I,—Methods Employed to Determine the Numbers of Bacteria in Water,..... 334
Plating,..... 335
Temperature,..... 336
Number of Days during which Plates were Allowed to Develop,..... 338
Reaction of Media,..... 339
Table of Temperatures in Thermostat,..... 342
Part II,—Species of Bacteria,..... 344
Species of Bacteria Found in the Allegheny River Water before and after Filtration,... 344
Application of Bacillus *prodigiosus*,..... 345
Species of Bacteria Found in Samples of Allegheny River Water,..... 346
Tests for Bacillus *coli communis*,..... 348
Tabulation of Results,..... 348
Part III,—Micro-Organisms,..... 349
Gate Chamber,..... 350
Settling Basin,..... 350
Effluents,..... 350
Highland Reservoir,..... 350
Herron Hill Reservoir,..... 351
Bedford Basin,..... 351
South Side Reservoir,..... 351
Wilkinsburg Reservoir,..... 351
Tabulation of Results,..... 352
Appendix No. 5, Report upon Driven Well Supply, by A. B. Shepherd, Supt.,..... 360
Appendix No. 6, Financial Statement,..... 361
Index,..... 363

LIST OF MAPS, PLANS, AND DIAGRAMS.

PLATE NO. PAGE.
1. Reported Number of Cases of Typhoid Fever, in each Ward of Pittsburgh, 1892-1897,..... 22
2. Location of Reported Cases of Typhoid Fever in Pittsburgh in 1897,..... 24
3. Water-Shed of Allegheny River,..... 30
4. Water-Shed of Monongahela River,..... 32
5. Average Monthly Temperatures at Pittsburgh, January, 1887, to September, 1898, 34
6. Monthly Precipitations at Pittsburgh, January, 1888, to September, 1898,..... 36

PLATE NO.		PAGE.
7.	Bacterial Efficiencies of Mechanical Filters, with various Quantities of Sulphate of Alumina,	52
8.	Amounts of Sulphate of Alumina actually Used with Mechanical Filters with Water of various Degrees of Turbidity and the Amounts necessary for Clarification,	56
9.	Location of Filters and Land, Included in Estimates of Cost,	66
10.	Estimated Consumption of Water with and without Meters and Comparison of Annual Charges of Present Supply Filtered with a Gravity Supply,	84
11.	Proposed Indian Creek Reservoir and Conduit to Pittsburgh,	100
12.	General Plan of Experimental Filter Plant,	114
13.	General Plan of Filter Building,	116
14.	Plan and Section of Sand Filters,	118
15.	Plan of Warren Filter,	156
16.	Elevation of Warren Filter,	156
17.	Plan of Jewell Filter,	182
18.	Elevation of Jewell Filter,	182
19.	Plan of Worms Tile Filter,	204
20.	Elevation of Worms Tile Filter,	204
21.	Test Well at Brilliant Pumping Station,	360

To the Presidents and Members of the Select and Common Councils of the City of Pittsburgh:

Gentlemen:—

In pursuance of the authority given by an ordinance approved June 10, 1896, the undersigned were appointed as an investigating body, charged with the following duties:—

1. To thoroughly investigate the character of the present water supply of the city of Pittsburgh in its relation to public health.

2. To ascertain the effect of sand filtration.

3. To ascertain the advisability of establishing a sand filtration plant for the city of Pittsburgh.

4. To present an estimate of the cost of establishing and maintaining the same.

5. To investigate the feasibility and advisability of seeking other sources of supply.

6. To report its findings and recommendations, together with such evidence as may be useful for the guidance of the Councils of the city of Pittsburgh, in acting prudently and for the best public interest in this matter.

The constitutionality of the legislation under which we had been appointed having been affirmed by the proper legal authorities, an organization was effected on July 6, 1896, by the election of Mr. Robert Pitcairn as Chairman, Mr. William McConway as Vice-Chairman, and Mr. Geo. L. Holliday as Secretary.

A committee upon Methods of Procedure, consisting of Dr. W. J. Holland, Chairman, Dr. J. R. Vincent and Hon. William Flinn, was appointed at the first meeting, and, in accordance with the recommendations of this committee, certain phases of the questions proposed to us for consideration were assigned to the general oversight of special sub-committees; the Chairman appointing them as follows:—

On Water Analysis;

Dr. W. J. Holland, *Chairman,*
Dr. J. Guy McCandless,
Dr. J. R. Vincent.

On General Information;

Mr. William McConway, *Chairman,*
Hon. H. P. Ford,
Mr. Geo. L. Holliday.

On Other Sources of Supply;

HON. WM. FLINN, *Chairman*,
MR. E. M. BIGELOW,
MR. S. D. WARMCASTLE,
MR. JAS. M. BAILEY.

As the result of frequent conferences and preliminary investigations it was decided that in order to carry out the instructions contained in the ordinance it would be necessary to employ the services of competent experts to investigate, under the general direction of the Commission, the various problems which might present themselves.

Accordingly, with the consent and sanction of your Honorable Bodies, the Commission secured the services of the following persons:—

As Consulting Engineer, Mr. Allen Hazen, of New York City.

As Resident Engineer, Mr. Morris Knowles, of Lawrence, Mass.

As Chemist, Walther Riddle, Ph.D., of the City of Pittsburgh.

As Bacteriologist, Mr. Wm. R. Copeland, of Lawrence, Mass.

Subsequently, as the necessity for increasing the force was shown, a number of other persons were employed to assist in the prosecution of the labor of investigation.

The Commission has held seventy sessions, at which reports of progress were regularly submitted by the Resident Engineer. Various questions coming up from time to time for consideration were discussed and reports were submitted, when called for, by the standing committees and by special committees, which were from time to time appointed. The Commission as a body, on November 11, 1896, visited the city of Lawrence, Mass., for the purpose of inspecting the filtration beds in operation in that city, and on their return, devoted a day in the city of New York to the inspection of certain plants engaged in mechanically filtering private water supplies. On April 19 and 20, 1898, the Chairman of the Commission, accompanied by the Chairman of the Committee on Water Analysis, the Mayor of Pittsburgh, and the Resident Engineer, visited the cities of Louisville, Ky., and Cincinnati, Ohio, for the purpose of investigating the methods and results of the extensive experimental plants established in these cities, and also visited the city of Covington, Ky., and examined the water works of that municipality. Availing themselves of the opportunities of foreign travel, several members of the Commission visited and carefully inspected filtration plants on the other side of the Atlantic. Mr. Wm.McConway visited the

filtration beds and the sewage treatment plants of London, England. Hon. William Flinn visited the filtration plant of Hamburg, Germany. Dr. W. J. Holland visited the filtration plants of London, Paris, Antwerp, Bremen, Hamburg, and Berlin. Mr. E. M. Bigelow visited the filtration plant at Hamburg. All of these gentlemen reported to the Commission the results of their observations. The members of the Commission have borne all expenses involved in visits paid to other localities, whether in this country or abroad, without recourse to the funds placed at the disposal of the Commission.

THE CHARACTER OF THE PRESENT WATER SUPPLY OF THE CITY OF PITTSBURGH IN ITS RELATION TO PUBLIC HEALTH.

We find that the present water supply is objectionable, first on account of the mud which it frequently carries, and secondly, because of its pollution by sewage. An ocular inspection of the Allegheny and Monongahela Rivers and their main tributaries, made under the direction of the Commission, reveals the fact that from the very summit of the mountains to the intakes all are more or less contaminated by sewage, and the reports of the Bacteriologist of the Commission show the presence of bacteria in objectionable quantities, both in the river water and in the tap-water as delivered.

Your Commission has arrived at the conclusion that with the proper filtration of the water supplies furnished to the people, water-borne diseases, which are so prevalent in this community, would, undoubtedly, be greatly lessened. If, in addition, more stringent regulations against the sale of infected milk and ice were enacted and enforced, and the use of water from springs and wells and of unpurified supplies of water in mills and factories were prevented, they would be almost wholly eradicated, except as the result of secondary infection from cases imported into the community.

THE EFFECT OF SAND FILTRATION.

Elaborate experiments extending over a period of time of sufficient length to show the effects of filtration upon the water of the Allegheny River in all seasons and at all stages have been carried on, as is detailed at length in the reports hereto appended, (See Exhibits 2, 4, and 5). These investigations show the entire feasibility of so treating the water by several methods as to remove both the mud and the deleterious vegetable growths contained therein.

Of the various methods of filtration which have been examined two have proved themselves efficient, the method of mechanical filtration and the method of sand filtration. The latter, which has been extensively

employed for many years past in Europe and also in this country, has yielded upon the whole somewhat better results than the former. As is fully set forth in the reports of the experts employed by the Commission, and as is shown in the tables which are thereto appended, the method of sand filtration not only yields a supply of water free from mud and objectionable bacterial life, but also furnishes a supply of water of a quality adapted to mechanical purposes, suited to the uses of industrial establishments. An investigation of this latter phase of the question was undertaken under the instruction of this body, and the results are hereto appended. (See Chapter VI, of Exhibit 4).

THE ADVISABILITY OF ESTABLISHING A SAND FILTRATION PLANT FOR THE CITY OF PITTSBURGH.

We find that it is in the highest degree desirable that the water supplied to a great municipality like Pittsburgh should be clear and free from objectionable matter, as well as of sufficient softness to permit of its use for domestic and mechanical purposes, and, as it is possible to furnish such a supply by one or the other of two methods the problem resolves itself into the question, which of the two is, on the whole, better adapted for the public service; taking into account:—

(a) *Comparative cost.*

(b) *Efficiency.*

(c) *Durability, as evidenced by its probable freedom from decay or wear and consequent necessity for repairs.*

(d) *Simplicity of operation.*

Comparative Cost.

If a conclusion were to be arrived at upon a consideration of initial cost, alone, the decision would doubtless be prompt. While the cost of bare construction differs but slightly as between the two plans, the cost of the larger body of land, required for the sand filtration plant, would be determinative, in favor of mechanical filtration, were other things equal.

Efficiency.

An examination of the relative efficiency of the two methods, in the light of actual experiment, shows that so far as the removal of bacteria from the water is concerned the sand filter leaves but little to be desired. In addition to bacterial efficiency and somewhat important, is the question of the adaptability of the effluent for steaming purposes. The effluent which yields a minimum scale formation, and shows no corrosive action upon the points in a boiler generally first exposed to at-

tack, is, all other things being equal, to be preferred. We find that the weight of evidence, obtained by experiment, is in favor of sand filtration; so far as efficiency in this respect is concerned.

Durability.

There being in the sand filters practically no metallic material except valves and connecting piping, common to both systems, it may be said to be subject to deterioration only by actual abandonment; by decay, never. In some of the filtration plants, visited by members of this board, are found sections in operation and as sound as though built but yesterday, which have already done service for forty years, and bid fair to render efficient service for many times this period. No plant built under the plan of mechanical filtration could be expected to yield such results. All mechanical devices are subject to rapid deterioration through wear and tear. It is generally assumed by careful manufacturers that the life of a machine in constant use does not exceed ten years. This being the case, the finding as to the question of durability is decidedly in favor of the system of sand filtration.

Simplicity of Operation.

In operating a plant of such magnitude as will be required to provide a full supply of pure water to this large and growing city it is of the first importance to do it on such lines as not to require, necessarily, the higher grades of technical skill on the part of a large proportion of the operatives. The sand filter meets this requirement to such an extent as to be fairly considered ideal. When properly constructed, slight neglects and errors of judgment on the part of workmen cannot damage the water. With any filter using coagulant the conditions are different; nice judgment is required to determine from day to day, and at times from hour to hour, the required quantity of that coagulant, and if there be not the proper quantity of lime in the water, initially, that must also be provided. The report of the Consulting Engineer (Exhibit 2) presents the detail of the operation in such full form that your Commission thinks it proper to call your attention to this feature and urge a careful study of the same. The choice lies between a system, which, when properly constructed, *cannot* furnish impure water, except as the result of wilful neglect, and one which *can* furnish pure water, but which can also, when carelessly or ignorantly handled, easily produce water unfit for domestic or mechanical use. The weight of evidence is found by the Commission to be decidedly in favor of sand filtration, so far as simplicity of operation is concerned.

The facts that no patents and consequent charges on this account are to be met in case of the use of sand filters, is an additional consideration

which has had weight with us in reaching a conclusion to recommend the use of sand filters. Finally the fact that the sand filters have been in sucessful use in England and on the continent of Europe for more than forty years and are employed by more than thirty of the great transatlantic municipalities; among them, being London, Berlin, Hamburg, Bremen, and the suburbs of Paris, with unvarying satisfaction, is a circumstance which has had great weight with us.

In view of all the foregoing considerations we find the adoption of the system of sand filtration to be the most advisable.

THE COST OF ESTABLISHING AND MAINTAINING A SYSTEM OF SAND FILTRATION.

We find that the cost of construction of sand filters with sedimentation basins and all accessories complete may be estimated at $1,691,000. To this should be added the cost of the necessary land. Should the land cost $420,000, the total estimated cost will be $2,111,000. The cost of maintenance in the case of sand filters with sedimentation basins, providing 50,000,000 of gallons daily, would amount, according to the figures submitted by our Consulting Engineer, to $192,184, of a cost of $10.53 per million gallons. This estimate includes interest, depreciation, and all operating expenses.

THE FEASIBILITY AND ADVISABILITY OF SEEKING OTHER SOURCES OF SUPPLY.

The results of our investigation in reference to this matter are set forth in full in the report of the Consulting Engineer (Exhibit 2), and in the report of Mr. Emil Kuichling, C. E., of Rochester, N. Y. (Exhibit 3), who was employed to make a full examination into the feasibility of introducing a water supply from the water-shed of Indian Creek. We find that the initial cost of introducing a supply from this source, which appears to be the most available of all sources of gravity supply, would be thirteen and a half millions of dollars, and the expense of the undertaking, together with the uncertainty of being able, except at a vast additional expense, of adding to this supply after the lapse of a comparatively short time, make the project one to which we cannot set the seal of our approval.

Auxiliary Supply.

We have examined into the question of furnishing a supply of potable water for household consumption separate from the supply furnished to mills and factories, but find that the consumption of water by the mills and factories is not great enough to justify the large expense that would be involved in providing pipes to convey separate supplies,

and we deem it, furthermore, eminently desirable, inasmuch as water is freely used in the mills and factories for drinking purposes, that the supply of water furnished these establishments should be of a good character from a sanitary standpoint. For these two reasons we cannot recommend a sparation of the two supplies.

Use of Meters.

We conclude as the result of careful investigations that the city is now wasting more than twice as much water as it uses. We find that the experience of other cities reveals that the introduction of a system of sale by meter has the result of greatly reducing the waste, and we strongly recommend the adoption of the meter system for the sale of water. We believe that the introduction of the use of meters will prevent waste to such a material extent as to greatly lessen the cost, alike of the establishment of a system of filtration and its subsequent operation, and possibly to make it feasible, from a plant of the size suggested in the report of the Consulting Engineer to supply, not only the portions of the city now using water of the Allegheny, but those also which are drawing their supply from the Monongahela.

Conclusion.

We recommend, in conclusion, that the city of Pittsburgh adopt, for its water supply, the system of sand filtration upon the plan recommended herewith in the report of our Consulting Engineer, and that the system of selling water by meter be likewise adopted. For the erection of a filtration plant approximately $1,700,000 will be required; to provide the necessary site $500,000 should be amply sufficient; to establish the meter system will require an additional outlay of $600,000. We recommend that your Honorable Bodies make provision for an issue of bonds for these purposes to the amount of $3,000,000, the bonds to be issued by the proper authorities as they may be required, and no more to be issued than are actually required to provide for the establishment of a system of filtering and metering the water supplied to the city. In recommending an issue of bonds to the amount of $3,000,000 we have allowed $200,000 for contingencies, which might, but are unlikely to, arise, and we believe that the sums above named will be quite sufficient to make it sure that all the water supplied the municipality will be wholesome, as it certainly will be clear and free from mud.

We append to our report the following papers:—

1. Report upon the Sources of Typhoid Fever in Pittsburgh, by Prof. William T. Sedgwick, Ph. D.

2. Consulting Engineer's Report, by Allen Hazen, C. E.

3. Report upon a Gravity Water Supply from Indian Creek, by Emil Kuichling, C. E.

4. Resident Engineer's Report, by Morris Knowles, C. E.

5. Appendices to the Resident Engineer's Report, (Appendices 1-6).

Respectfully submitted,

ROBT. PITCAIRN, *Chairman.*
WILLIAM MCCONWAY, *Vice Chairman.*
GEO. L. HOLLIDAY, *Secretary.*
HENRY P. FORD, *Mayor.*
S. D. WARMCASTLE.
J. R. VINCENT.
W. J. HOLLAND.
E. M. BIGELOW.
JAMES M. BAILEY.
J. GUY MCCANDLESS.
WM. FLINN.

REPORT

UPON

The Sources of Typhoid Fever

IN PITTSBURGH.

BY

WILLIAM T. SEDGWICK,

Professor of Biology and Lecturer on Sanitary Science,
Massachusetts Institute of Technology;
and Consulting Biologist,
State Board of Health of Massachusetts.

EXHIBIT I.

MR. ROBERT PITCAIRN,

Chairman, Filtration Commission;

Pittsburgh, Pennsylvania.

SIR:—

In accordance with your instructions, I have made a thorough investigation of the probable sources of typhoid fever in Pittsburgh, and have the honor to respectfully submit herewith a formal report upon the same I have followed as closely as possible in making this report the lines along which I proceeded in making a preliminary report to the Commissioners, when I personally appeared before them in September. It will appear from what follows that such investigations and studies as I have been able to make in the interval, support the conclusions and strengthen the opinions which I laid before the Commission at that time.

TYPHOID FEVER HAS BEEN THE CAUSE OF MANY DEATHS AND IS CONSTANTLY PRESENT IN PITTSBURGH.

The vital statistics of Pittsburgh show conclusively that typhoid fever has for many years been an important factor in the death rate of the city. During the past decade it has been the assigned cause of 2,245 deaths, an average of 224.5 deaths per annum. During these last ten years, and probably for a very much longer period, Pittsburgh has never been wholly free from typhoid fever, but on the contrary most of the time has contained a large number of cases; for at no time within the last ten years have there been fewer than four deaths per month attributed to this disease, while the monthly average has been very much larger, namely, 18.7 deaths. These figures mean that during the last decade there have been in the city of Pittsburgh very rarely, if ever, at any one time, fewer than one or two score of cases of typhoid fever, while there has been on the whole a probable average of between 150 and 200 cases at any given time.

It is Excessive in Amount.

The average annual number of deaths in Pittsburgh during the last ten years (1888-1897) is 224.5 and the (estimated) population in 1895 was 275,000. During the same period the average annual number in Boston was much smaller (158.9) with a population much larger, viz: in 1895, 496,620. For the same period in New York, the figures are: population in 1895; 1,669,801—the average number of deaths from typhoid fever per annum, 352.2 Otherwise stated this means a rate per annum per 100,000 inhabitants, of 21.0 in New York City, 31.9 in Boston, and 81.6 in Pittsburgh. These figures show conclusively that the amount of typhoid fever

in Pittsburgh is excessive, and as I believe it is admitted on all sides that such is the fact, I shall not dwell further upon this aspect of the subject.

THE SOURCES OF TYPHOID FEVER IN CITIES.

It is now everywhere admitted that typhoid fever does not arise spontaneously but comes only from antecedent cases of the same disease from which it is conveyed in various ways to fresh victims. The medium of communication in these cases is often spoken of as the "vehicle" of the disease, and the following are some of the principal vehicles by which it is so conveyed:

1. *Water Supply.*
2. *Milk Supply.*
3. *Ice Supply.*
4. *Secondary Infection or Contagion.*
5. *Infected Uncooked Food, such as Oysters, Vegetables, Fruits, etc.*
6. *Atmospheric Dust.*

Any or all of these vehicles may be the immediate sources of typhoid fever in a city; the remote source in all cases being understood to be the body of a patient affected with the disease. In searching for the causes of the excess of typhoid fever in Pittsburgh, we must naturally consider in detail each of these several possible sources, and we may do this taking them up in the reverse order to that in which they have just been enumerated.

Atmospheric Dust.

In any city in which typhoid fever is abundant it must be allowed that there may be a continuance of the disease for a time, owing to the causation of a certain number of secondary cases through the medium of atmospheric dust, especially if disinfection is not very thoroughly carried out for the primary cases.

The present state of our knowledge, however, in regard to the dissemination of typhoid fever by means of dust is not such as to allow us to attribute to this source any considerable number of cases and we need not hesitate to dismiss this as in any great degree an adequate explanation of, although it may well be a contributory cause to, the sum total of typhoid fever in Pittsburgh.

Infected Uncooked Food, (Oysters, Vegetables, Fruits, Etc.)

It is generally held by sanitarians that uncooked food, especially such as has been handled by various people, and, in particular, raw oysters which may have been cultivated in sewage-polluted waters; lettuce which may have been watered with impure liquids; celery which may have been

manured with night-soil and afterwards imperfectly cleaned for the table; or fruits, such as cherries, grapes, apples, pears, peaches, berries and the like which are often handled by unclean persons and then eaten without having been thoroughly washed, may readily be vehicles of the germs of typhoid fever. I have not, however, been able to discover that Pittsburgh is peculiar in any of these respects (unless possibly it may be in the consumption of raw oysters brought from sources, the precise sanitary condition of which is not known), and I do not believe, therefore, than any considerable proportion of the total typhoid fever of Pittsburgh can be charged to these sources, although it should never be forgotten that they may be important contributory factors in a case like this and, in cities having only a small amount of the disease, may even be the principal factors. Special attention has lately been drawn by army officials to the probable importance of flies as bearers of infection from excreta to articles of food which are afterwards eaten raw; but even allowing this to be true it does not suffice to explain the peculiar state of affairs in respect to typhoid fever in Pittsburgh.

Against the supposition that the food supply as described is responsible to any considerable extent for the typhoid fever in Pittsburgh is the notable fact that the cases appear to be, on the whole, quite evenly distributed according to population throughout the city. These facts do not support the view that the disease has its origin in infected foods, for any general infection of the entire food supply of the city cannot well be supposed to be constantly recurring.

Secondary Infection or Contagion.

It is otherwise as regards the part probably played by secondary infection or contagion. Contrary to the popular belief, typhoid fever is, in a true sense, a contagious disease, although far less so than the more eruptive diseases such as scarlet fever, measles, small-pox, and also probably much less contagious than certain other diseases such as diphtheria. When, therefore, there is for any reason a considerable number of cases of typhoid fever in any city or town, it follows almost inevitably that there will be a considerable number of cases secondary to these and derived from them, which will form another important contributory factor in making up the sum total to be found during any considerable period. I have examined carefully the reports of cases on file in the Bureau of Health and have satisfied myself that Pittsburgh forms no exception to this general rule; for a considerable number of cases appear upon the books which are plainly secondary to other cases, and I am informed by prominent physicians that such examples are by no means rare. This factor, however, like those which have already been discussed, would, in itself, be of small

moment if there were no primary and more permanent causes making up the principal part of the total.

Ice Supply.

Although it is customary for sanitarians to turn to the ice supply of cities as an important source of typhoid fever, the latest and most trustworthy investigations on this subject do not support the idea that any considerable number of cases, even in a large city using a comparatively impure ice supply, can be traced to this source, and it is a remarkable and important fact that no epidemic or other excess of typhoid fever has ever yet been indisputably traced to infected ice. Moreover, inasmuch as artificial ice, made from distilled water, is almost exclusively used in Pittsburgh for household purposes, it is altogether improbable that any excess of typhoid fever could come from this source; but, at the same time, as the use of pond or lake ice is not prohibited, it is very likely that the latter is used occasionally. Accordingly, while it is possible that a few out of the large number of cases in Pittsburgh can be charged to this source, I do not believe that any considerable number has come from impure ice and we may properly consider this factor as perhaps contributory to, but cannot possibly regard it as the principal cause of, the large amount of typhoid fever constantly present in Pittsburgh.

Milk Supply.

Within the last score of years a large number of cases of typhoid fever in various parts of the world have been traced in the most positive manner to polluted and infected milk supplies, and no fact in sanitary science is better established than that milk infected with typhoid fever is not only comparatively speaking, common, but also highly effective as a vehicle of this disease. I have inquired carefully in regard to the milk supply of Pittsburgh, and I am of the opinion that in all probability a certain amount of the typhoid fever which prevails in this city, and has prevailed for many years, may reasonably be attributed to infected milk.

At the same time, epidemics due to infected milk are always occasional and sporadic, not constant and general, and it is a well-known characteristic of typhoid fever due to milk supplies that the disease appears in special areas with marked violence only for a limited time. It is, therefore, quite clear that while the milk supply may have been, and probably has been, an important contributory cause to the sum total of typhoid fever in Pittsburgh, it is manifestly not the principal cause, which must be something constant and general, instead of occasional and sporadic.

The Public Water Supply.

There remains for consideration only one important source of typhoid fever in cities, namely, the public water supply; and, inasmuch as by ex-

clusion we have determined that the other principal sources of typhoid fever in cities are here inadequate to furnish any sufficient explanation of the typhoid fever which is so constantly and so excessively prevalent in Pittsburgh, we shall need to give to the public water supply the most careful consideration.

It is well known to your Honorable Board that Pittsburgh is provided with two principal sources of supply, namely, the Allegheny and Monongahela Rivers, and that most of the supply is derived from the Allegheny. In both cases the water which is delivered to the citizens is drawn directly from the river without filtration or other purification of any sort, then immediately pumped to distributing reservoirs and from these quickly sent all over the city.

From the standpoint of modern sanitary science, this procedure is *prima facie* most objectionable, inasmuch as the delivery to the people of unpurified river water is nowadays everywhere regarded as extremely dangerous, such water has been too often found to be a fruitful source of typhoid fever and kindred diseases. In the present instance, however, it will not suffice to rely simply on the facts just stated, straightway concluding that we have in the public water supply an all-sufficient explanation of the constant and excessive amount of typhoid fever in Pittsburgh. We cannot indeed escape the natural suspicion that this may be true; but before coming to any final conclusion in regard to a matter necessarily so complex and obscure as the sources of typhoid fever in a great city, we must first examine closely all the evidence in hand, and especially local conditions, in order to verify any preliminary conclusions which may be reached; and this all the more, because such conclusions may involve important changes in public policy and the expenditure of large sums of public money.

THE WATER SUPPLY DERIVED FROM THE MONONGAHELA RIVER.

The water of the Monongahela River is used by a limited portion only of the city, namely, that lying upon the south side of the same river and including wards Twenty-four to Thirty-eight inclusive, with the exception of ward Thirty-seven. The total estimated population of these wards for 1897 is about 78,000, that is to say, about one-fourth of the whole population. In addition to the urban population using this water, it is furnished to about twenty-five thousand people living in the boroughs immediately adjacent to the city.

The Monongahela River and its upper affluents, rising in the extensive forests of West Virginia, flows for the greater part of its course though a sparsely inhabited region, and, owing to the fact that it has been slack-watered over almost its entire course, the process of sedimentation goes on extensively, so that it might furnish an admirable water supply

were it not for the fact that in its lower reaches it is heavily contaminated by sewage. The sewers of the city of McKeesport, of the boroughs of Homestead, Braddock, Duquesne, and other lesser places, all empty into the river above the intake of the Monongahela Water Company, and as the growth of the population in these towns and city is rapidly increasing, it is presumable that the amount of sewage emptied into the Monongahela River is destined likewise to increase. I am of the opinion that the general use of this contaminated water is in itself alone an adequate explanation of the great amount of typhoid fever which has at times prevailed on the South Side. This conclusion is confirmed by the results obtained by the Bacteriologist of your Commission, Mr. Wm. R. Copeland, who has found repeatedly in his examinations of the tap water derived from the Monongahela, as well as in the river itself, large numbers of bacteria. Inasmuch, therefore, as micro-organisms abound in the river water, the latter is presumptively the ready vehicle for the specific germs of typhoid fever which we have every reason to believe enter the river from time to time with the sewage which it so freely receives in its lower reaches.

In the absence of any other adequate explanation for the typhoid fever constantly recurring on the South Side, and in the presence of a simple and sufficient explanation in the consumption by the people of river water unpurified and polluted with sewage, I have no hesitation in affirming that it is probably the water supply which is the principal source of the typhoid fever of the South Side.

Furthermore, we must not overlook the fact that when any part of a community is supplied with infected water, other parts, and possibly all parts, may also suffer from it. If, for example, a dweller on the north side works in a mill or a house on the South Side, or even only visits there, he or she may, by drinking infected water on that side, become infected and, returning home, not only suffer from the disease but also become a center of infection and cause others on the north side to suffer likewise.

THE WATER SUPPLY DERIVED FROM THE ALLEGHENY RIVER.

In the case of the Allegheny, which supplies the principal portion of Pittsburgh, namely, that part of it lying between the two rivers and including the great mass of the population, the case is by no means at first sight so clear. The Allegheny drains a very extensive, and not very thickly inhabited, water-shed and much of the population is at a considerable distance from the intake. Nevertheless, the water thus derived is still a river water, wholly unpurified, except for such sedimentation and other improvement as occurs in the distributing reservoirs; and a close examination of the character and sanitary condition of the water, and the water-shed, of the Allegheny River, especially in the light of modern sanitary science, is not reassuring.

It was for a long time believed, even by engineers and sanitarians that "running water purifies itself." The facts upon which this thesis rested were the obvious disappearance of gross pollution, introduced at a given point in a stream, at points below, and chemical evidence that water drawn at such lower points was less polluted than at the place of contamination. Trusting in this principle, and following the advice of the best engineers of the time, numerous cities and towns, Pittsburgh among the number, introduced systems of water supply derived directly, and without any attempt at purification, from rivers and other streams into which, at points above, more or less of sewage and other polluting materials were freely admitted. Very early, however, it began to be discovered that the purification, which was so obvious on inspection and was further demonstrable by chemical analysis, was, from the sanitary point of view, incomplete and insufficient. As long ago as 1874 the Rivers Pollution Commissioners of the British Government, after careful investigation, concluded that, "there is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source." From that day until the present it has gradually become more and more clear that such purification as takes place is largely, if not almost wholly, a purification by dilution, and that many of the dangerous elements, especially micro-organisms, once admitted, are not in fact removed, but only scattered in a running stream or river. At the same time, it has also gradually become plain that sedimentation and the destruction of micro-organisms by various agencies are more completely effected in standing, than in moving water; so that modern sanitary science has reversed the tenet of thirty years ago and now unhesitatingly affirms that it is quiet water rather than running water that "purifies itself." As a corollary of this modern doctrine, which is supported by an overwhelming mass of evidence, it follows as a matter of course that those cities and towns which, trusting in the earlier teaching, unwisely introduced systems of supply yielding water drawn, unpurified, directly from swiftly running streams, are now finding themselves in an unfortunate predicament; for in many of them it has been discovered that typhoid fever and kindred diseases are alarmingly abundant and the conclusion is natural—inevitable even—that in all probability the excess of typhoid fever from which many of them suffer is due to their use of unpurified, sewage-polluted, river water. In some cases, to be sure, it appears that cities and towns so situated do not suffer excessively from this disease, but when this is the case it will generally be found to be true that certain local conditions, readily discoverable, explain their apparent immunity.

We may now proceed to a detailed consideration of the character of the Allegheny River and the water-shed from which it is derived in order to discover, if possible, whether or not the conditions which prevail in this

case are such as to favor immunity from, or the prevalence of, typhoid fever among those to whom the water is distributed. Before doing this, however, it will be well to enumerate those conditions which, in general, favor and those which hinder the self-purification of streams. The principal condition favoring self-purification is, as has been stated above, quiescence; and closely connected with this condition is the element of time, because quiescence is merely a relative term. It is conceivable that water might be kept quiet for only a few minutes with very little advantage,—for a few minutes or even a considerable portion of an hour, without any appreciable purification by sedimentation, or by the germicidal action of light, or by other influences tending toward sanitary improvement The time element is also important because there is reason to believe that the germs of typhoid fever do not ordinarily multiply in natural waters, at least in northern latitudes, but, instead, gradually die out. Other things equal, therefore, a slow and quiet stream is comparatively well adapted for self-purification. Other factors of consequence in a case of this kind are the population upon the water-shed,—whether abundant or scanty,—its character, whether gathered in towns and villages or sparsely distributed over a great area in the form of rural population; and, in general, as has frequently been claimed, the proximity or remoteness of such population. We may now examine one by one these items which together go to make up the character of a river water, and inquire more precisely as to the conditions which prevail upon the stream in question, viz., the Allegheny River.

THE ALLEGHENY RIVER IS A RAPID STREAM WITH LITTLE OR NO OPPORTUNITY FOR SELF-PURIFICATION.

Any one who will take the trouble to follow the Allegheny River from Oil City to Pittsburgh, merely as a passenger on the Allegheny Valley Railway, particularly if he is familiar with the streams in the less mountainous parts of the country, cannot fail to be impressed immediately with the fact that we have in the Allegheny River a peculiar and characteristic stream. Owing no doubt to the character of the rock through which it has cut its way, it exhibits a very regular decline from Oil City to Pittsburgh. There is no mill-dam of any consequence between these two cities and the river is therefore not, as is frequently the case with rivers in New England and elsewhere a series of mill-ponds, containing slowly-moving water, and in which the elements of sluggishness and quiescence are, except in periods of freshet, the chief characteristics; but rather, even at low water, like a brawling brook making its way rapidly over a stony bed in which are very few pools or other quiet places adapted to purification; in which there is little or no evidence of effective sedimentation,—as is proved by the absence of mud-banks, sand-bars, and the like,—but exhibiting everywhere

stones polished by the swiftly-flowing stream, and without effective lodging places for mud or bacteria. An estimate, roughly made, of the rate of flow shows to the traveler a probable velocity in most places of at least a foot per second, and often much more than this, even at low water. With high water the velocity must obviously be much more rapid. Clearly, the two fundamental elements looking towards self-purification in rivers are here wanting, namely, time and quiescence. The velocity of the river and the character of its bed are such that foul water introduced, for example, at Oil City, or nearer points, may, and indeed must, arrive at Pittsburgh within a very few hours. Fortunately, however, we do not have to rely on the rough observations of passing travelers but are in possession of authoritative calculation. According to results obtained from the United States Engineer's Office in Pittsburgh, the average velocity of the Allegheny River, even during low water, is from one to two miles per hour. During high water it is from seven to eight miles per hour and on the average about three and one-half miles. This means that infectious materials poured in at Oil City or nearer points may arrive at Brilliant within fifteen hours and even at low water must arrive within a few days.

It has just been shown that in the bed of the Allegheny River very little or no opportunity occurs for purification *en route* by the usual processes which are more or less effective in rivers, so that the only question that now remains is, may it not be true that the typhoid germs, if present, die out in the relatively unfavorable environment which the river water supplies? In answer to this question it need only be said that the life of the typhoid germ in water, while it has been variously determined, is without question capable of extending over a considerably greater period than that required for the water of the Allegheny to pass even from remote points on the water-shed to the intake of the Pittsburgh Water Works at Brilliant, so that there seems to be no escape from the conclusion that typhoid fever infection introduced, even at remote points, may and often must be delivered to the citizens of Pittsburgh in an active and virulent condition. Oil City is distant from Pittsburgh (according to the United States Engineers) 113 miles. But such is the peculiar character of the river and such the character of the water-shed, that infection introduced at much more remote points than Oil City may, in my opinion, be actively dangerous to the health of Pittsburgh. I have never seen a river so well adapted in every respect to the swift conveyance of microscopical impurities from great distances.

As to the water-shed, it is hardly necessary to do more than to point out that the Allegheny valley in which the river and the railroad run is essentially a cutting or canon, having steep sides and constituting what may be called a "quick-spilling" water-shed; in other words, given a

heavy shower or sudden fall of rain, the latter finds its way down the sides of the valley, almost immediately, into the river, naturally carrying with it as a vehicle whatever portable material it encounters. It follows as a matter of course that whatever infectious materials may be deposited on the surface of this valley may readily find their way into the river, and from what has been said above, be quickly delivered to the pumping station at Brilliant.

In effect, therefore, although the greater part of the population on the water-shed of the Allegheny is quite remote and at most not very large, the element of distance appears to be neutralized in this case by the peculiar character of the stream, and the result is the same as if a considerable polluting population were located just above the intake at Brilliant. It is difficult to exaggerate the importance of this peculiar condition of things; for it means that even a small contamination, though at a great distance, may bear fruit almost immediately in an increased mortality of the citizens of Pittsburgh.

It is well known that a relatively small infection of a water supply with typhoid fever germs may under special circumstances be highly effective. The great epidemic at Lowell and Lawrence, Mass., in 1890-91, was traced to a relatively small infection of a relatively insignificant feeder of the Merrimac River, from which the water supply of these cities was derived. In that case the germs of the disease passing out of the little feeder appeared to have mingled with the relatively large mass of water of the Merrimac River and to have found their way to the intake pipe, on the opposite side of the river, some three miles below. The element of proximity was there undoubtedly important because the Merrimac River is in effect a series of mill-ponds, the particular pond which was infected being some sixteen miles in length and affording at low water, abundant opportunity for sedimentation and other factors of self-purification. In the case of the Allegheny River, a similarly small infection washed in from the water-shed by a heavy shower, or finding its way in at any point on the main river or its larger tributaries, in the absence of any similar mill-pond features, and in the presence of a swiftly flowing stream. must be carried rapidly to the intake at Brilliant in a relatively fresh and virulent condition.

We have then obviously, in the case of the Allegheny River, a vehicle highly favorable for the conveyance of typhoid fever germs from almost any point upon the water-shed, however remote; and this is particularly the case whenever a heavy rainfall occurs, causing the river to rise and making it muddy. The mud in the river is familiar and visible evidence of the efficiency of the stream as a carrier of dirt and *debris*. But there is other and still more valuable evidence, namely, that supplied by bacteriology. The experienced Bacteriologist of

your Commission, Mr. Copeland, has from the beginning of the investigations kept close watch of the bacterial characteristics of the water of the Allegheny, not only as it arrives at the pumping station at Brilliant, but also during its brief stay in the reservoirs, and as it is drawn from the service pipes by the citizens; and his results show conclusively, not only that the Allegheny is a highly effective vehicle of bacteria,—which abound in its too-often turbid waters,—but also that particular kinds of bacteria are generally present which point unmistakably towards extensive sewage pollution. Among the myriads of ordinary bacteria of earth, air, water, and animal intestines, present in sewage, those of typhoid fever are so few that all search for them by competent observers is usually in vain. If it were not so, if the typhoid germs were so abundant is to be readily detected or even detected at all, any city using such water for drinking purposes must surely be depopulated; for even in sewage, in comparison with the whole number of common bacteria, those of typhoid fever are probably as rare as planets are among the stars, while, unlike the planets, they have no well marked features of size or motion which enable them to be readily distinguished from their neighbors, but rather so closely resemble many of them as to be distinguishable, even when found, only by long and patient study.

The germs of typhoid fever bear, on the contrary to the harmless germs of sewage some such relation as do murderers to ordinary citizens, in the passing crowd upon a busy street. They are very few in number and outwardly resemble very closely the law-abiding. Even expert detectives on the watch may not be able to discover them. It is only afterwards that often unseen and unsuspected, they do their deadly work. Even then they may escape detection in the crowd, and it is only when circumstantial evidence is overwhelming, or when they are taken in the very act, red-handed, that their true character becomes manifest.

The germs of typhoid fever in sewage-polluted water can rarely, if ever, be detected among the hosts of harmless organisms present and which they closely resemble. But if the use of such sewage-polluted, unpurified water is followed constantly by numerous cases of typhoid fever, there is, in the absence of other obvious causes, overwhelming circumstantial evidence of their presence. When, in addition, we remember that in this case typhoid fever is not uncommon on the water-shed; and that the latter is of such a character as to favor the speedy delivery of surface water to the citizens of Pittsburgh well inside the time during which the typhoid germ is known to retain its vitality and virulence in water; the case, in the absence of any other reasonable explanation, and of any shadow of evidence, even in opposition, becomes so strong as to amount to a demonstration.

DISTRIBUTION OF TYPHOID FEVER IN PITTSBURGH.

The engineers of your Honorable Commission have prepared a map,[1] a copy of which I am kindly permitted by them to include in my Report, showing the typhoid mortality per 10,000 inhabitants in the various wards of the city. It should be stated at the outset that the population in each ward is somewhat uncertain inasmuch as no census by wards has been taken since the United States Census in 1890 (the Police Census in 1897 being by Police Districts), and it will not do, therefore, to depend absolutely upon the results given upon the map. Nevertheless these are very instructive.

It will be observed that no inhabited portion of the city is entirely free from the disease. Some wards appear to have suffered more severely than others, as would be expected when we recall the fact that typhoid fever arises from various sources for, as we have already pointed out, whatever the principal cause in Pittsburgh may be, numerous contributory causes unquestionably exist.

Another and perhaps more valuable aid in answering the question at stake, whether the distribution in general and broadly speaking, is conformable to the density of the population, is, perhaps, to be derived by observing the actual location of the cases of typhoid fever reported in Pittsburgh during the twelve months of 1897. A map[2] showing the location of these cases, and prepared under my direction by the Engineers of your Commission, is also appended as a portion of this Report. It will be observed that no part of the city which is at all thickly populated or likely to have used the city water, was free from the disease and that, broadly speaking, the cases appear to be distributed as nearly as might be expected in a case like this, according to the density of the population.

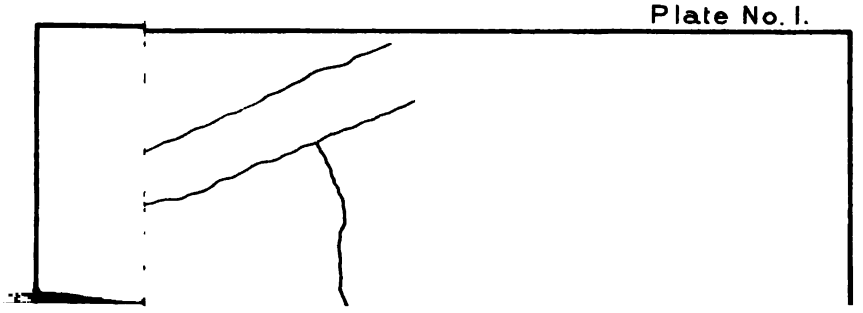
So far then as these methods of examination go, the one extending over six years and the other over one year, they tend to show precisely such distribution of the disease as might be expected from one principal and widespread source affecting all parts of the city. I must repeat that exact conformability to density of population cannot be expected owing to the varying influences of the several contributory factors which go to make up the total typhoid fever of any modern city; but in my opinion it is not unfair to conclude, from the facts of the distribution of typhoid fever and of a polluted water supply, especially in the absence of any other satisfactory cause and under the peculiar conditions represented by the Allegheny River, that there is a close and significant connection between the two.

---

[1] See Plate No. 1, opposite Page 22.

[2] See Plate No. 2, opposite Page 24.

Plate No. I.



THE ALLEGHENY RIVER NOT THE ONLY POLLUTED WATER SUPPLY OF PITTSBURGH.

It has already been pointed out that the Monongahela River is a most objectionable source of water supply for the South Side. The citizens of Pittsburgh itself are to some extent exposed to another and grave danger in the use, to a certain extent, of water taken directly from the Allegheny River by mills and manufactories and so disposed within these establishments as to be accessible to, and, in fact, to a considerable extent used for drinking by laborers and others therein engaged. Several of the manufacturing establishments located on the Allegheny River pump water taken directly from the river opposite their works and distribute it throughout the establishments for various purposes but in such a way that it is accessible for drinking. It is hardly necessary to say that these supplies must be highly objectionable, inasmuch as they are derived from a river not only extensively sewage-polluted above Brilliant, but also seriously polluted below Brilliant, yet above the establishments in question, by sewers of the city itself.

It is a well-known fact that consumers often will not stop to inquire whether a water is safe or not provided it is readily accessible and agreeable in taste or temperature; and I have no doubt that a considerable amount of typhoid fever in Pittsburgh in the past has arisen from this source. Even should the supply taken at Brilliant be purified by filtration I should expect to see some typhoid fever still prevailing in the city in part traceable to these mill supplies. It seems to me imperative that whatever else is or is not done these supplies taken directly from the river should be abandoned immediately, or else so arranged in the mills or other establishments in which they exist as to be inaccessible for drinking purposes.

I have already indicated above the fact that the use of Monongahela River water on the South Side may have caused some disease on the north-side, and the same line of reasoning would cause me to expect to find in Pittsburgh a considerable number of cases derived from the use of polluted waters in Allegheny, or other neighboring cities and towns. It is possible, also, that a few cases in Pittsburgh may be due to the use of infected spring waters which, even under high sounding names, are by no means always above suspicion.

SUMMARY AND CONCLUSION.

We may recapitulate as follows:—It is probable that a portion of the typhoid fever in Pittsburgh is derived from polluted milk, from secondary infection, from atmospheric dust, and from outside sources; but the constancy and general distribution of the disease point, in the strongest manner, to some other cause than these, which may indeed be regarded as contributory factors but cannot be regarded as its principal source. On

the other hand, the same facts which disqualify these as the principal causes strongly suggest some widespread, general, and constant source, such as the water supply would be; and on examining the character of the water supplied to Pittsburgh, it appears that it is derived from rapid and turbid rivers into which abundant sewage finds its way and by which such sewage is very speedily delivered, unpurified, to the consumers. In other words, the water supply fulfills precisely the conditions required to explain the facts. I am therefore forced to conclude that this is in all probability the principal source of the constant and excessive amount of typhoid fever in Pittsburgh.

Respectfully submitted,

WILLIAM T. SEDGWICK.

November 10, 1898.

Plate No. 2.

REPORT

OF THE

Consulting Engineer.

ALLEN HAZEN, C. E.

EXHIBIT 2.

MR. ROBERT PITCAIRN,

Chairman, Filtration Commission;

Pittsburgh, Pennsylvania.

SIR:—

I beg to submit the following report in regard to the water supply of Pittsburgh, and the means to be taken for its improvement.

The city of Pittsburgh, with a present estimated population of 320,000, is situated at the junction of the Allegheny and Monongahela Rivers. The city water works draw water from the Allegheny River at Brilliant, and supply a part of the city having a population of approximately 234,000, and most of this population is supplied from the city works. Another part of the city is supplied with water from the Monongahela Water Company, drawing water from the Monongahela River. The district supplied in this way has an estimated population of 78,000. The remaining portions of the city, with an estimated population of 8,000, are supplied by two other private companies.

The water as now supplied by the city works from the Allegheny River is at times very muddy. The river is also polluted by a considerable quantity of sewage, and there is reason to suppose that it is, or that it may become, injurious to health. We have to consider, therefore, first, whether or not the water as now supplied by the city works is unhealthy, or is likely to become unhealthy, and second, to determine the feasibility and cost of removing, by means of filtration or otherwise, the objectionable qualities, whether unhealthy or not; and third, to determine whether any other source of supply can be substituted to advantage for that now in use.

The question of the healthfulness of the Allegheny River water is found to present some very interesting problems. The amount of sewage entering the river is very much less, relatively, than the volumes of sewage entering other American rivers used for public water supplies; but notwithstanding this, the city has had an exceptionally high death rate from typhoid fever for many years. In view of the unusual difficulties of the question, the matter was referred to Prof. William T. Sedgwick, of the Massachusetts Institute of Technology, who has made a report thereon, which has been presented to you, and which deals with the matter quite fully.

In taking up the question of the feasibility and cost of purifying the Allegheny River water, a number of important questions presented themselves. Sand filters, operated at rates of from two to five million gallons per acre daily, have been used in many European cities and a

smaller number of American cities for many years, and have been conspicuously successful in removing those bacteria from surface waters whose presence would otherwise cause disease. Most of the waters so purified, however, have been drawn from lakes or reservoirs, or from rivers not subject to excessive muddiness; such rivers, for example, as the Merrimac and the Hudson in this country, and the Thames and the Spree in Europe, which do not approach in muddiness the Allegheny River at Pittsburgh.

It was known in a general way that special precautions had to be taken in the treatment of muddy waters by this process, but no data were available to determine the extent of the precautions, nor the exact results which could be obtained in the removal of mud. The crude petroleum, mine drainage, etc., which occur more or less regularly in the Allegheny River water, were also factors, the importance of which could not be determined without trial.

Another system of filtration, known as mechanical filtration, has been somewhat extensively used in the United States by cities smaller than Pittsburgh. This system of filtration is commonly used at rates of about 100 million gallons per acre daily, and chemicals, usually sulphate of alumina, are employed in connection with it, to assist the separation of the solid matters and to allow clarification to take place at higher rates than would otherwise be possible. This system of filtration has met with considerable success in the clarification of very muddy waters. Owing to the fact that it has principally been used for such waters, and rarely for the purification of waters containing considerable quantities of sewage, but few data were available as to its effectiveness in the removal of any disease producing qualities which might be present.

In view of this condition of affairs it was deemed advisable to make experiments upon a considerable scale with these two systems of filtration, to determine whether or not sand filtration was capable of clarifying the Allegheny River water, and whether or not mechanical filtration was capable of removing sufficiently the bacteria as well as the turbidity; and also to determine as far as possible the conditions essential to success with each system; as, for example, the rate of filtration which could be safely employed; the quantity of chemicals which it is necessary to use; the necessity of preliminary sedimentation, etc.

The two above mentioned methods of filtration are the only ones which have achieved conspicuous success, or have been adopted on an important scale. Other methods of filtration have been devised which have been tried experimentally, and in some cases municipal plants have been constructed upon them. In connection with our experiments,

therefore, we have made certain investigations, in part by experiments, and in part by examination of plants, experimental or otherwise, upon various other systems of filtration, to determine if there was anything in them which could be used to advantage in treating the water of the Allegheny River.

In estimating the cost of filtration, it has been necessary to consider the probable growth of the city and the possible extension of the municipal water supply to those parts of the city not at present supplied by the city works, and to make estimates of the amounts of water required for the proper supply of these populations. In this connection the prevention of waste of water is of vital importance, as it affects the quantity of water which must be provided, and consequently the cost of filters.

Estimates of costs of filters upon various systems and in various localities have been made in detail, which, in connection with the results obtained in our experimental trials of the various systems, show to what extent the Allegheny River water can be purified, and the cost of doing it.

It has been suggested that a large part of the water supplied by the city water works is used for manufacturing purposes, and that it might be possible, at reduced cost, to install a separate system to supply river water for such uses, and to provide filters for only that part of the supply required for domestic purposes. This plan, therefore, has been considered in comparison with the cost of filtering the whole supply.

All projects for the improvement of the present supply involve the construction of filter plants, and their operation, at a considerable expense; and they also involve pumping all of the water from the Allegheny River to the city reservoirs, as it is now done, at a heavy annual expense. If a source of supply could be found, high enough to flow by gravity through conduits to the city reservoirs, the cost of pumping would be saved; and if the water was derived from a sparsely populated water-shed, which could be controlled by the city, the necessity of filtration would be avoided. We have, therefore, made examinations to see if such a supply could be obtained; and having found such a source, we have made investigations as to the feasibility and cost of supplying the city of Pittsburgh in this manner. In connection with this study the services of Mr. Emil Kuchling, Chief Engineer of the Rochester Water Works, have been secured. In connection with the various problems here briefly outlined, very many studies and estimates have been made, which are given more at length under their respective headings.

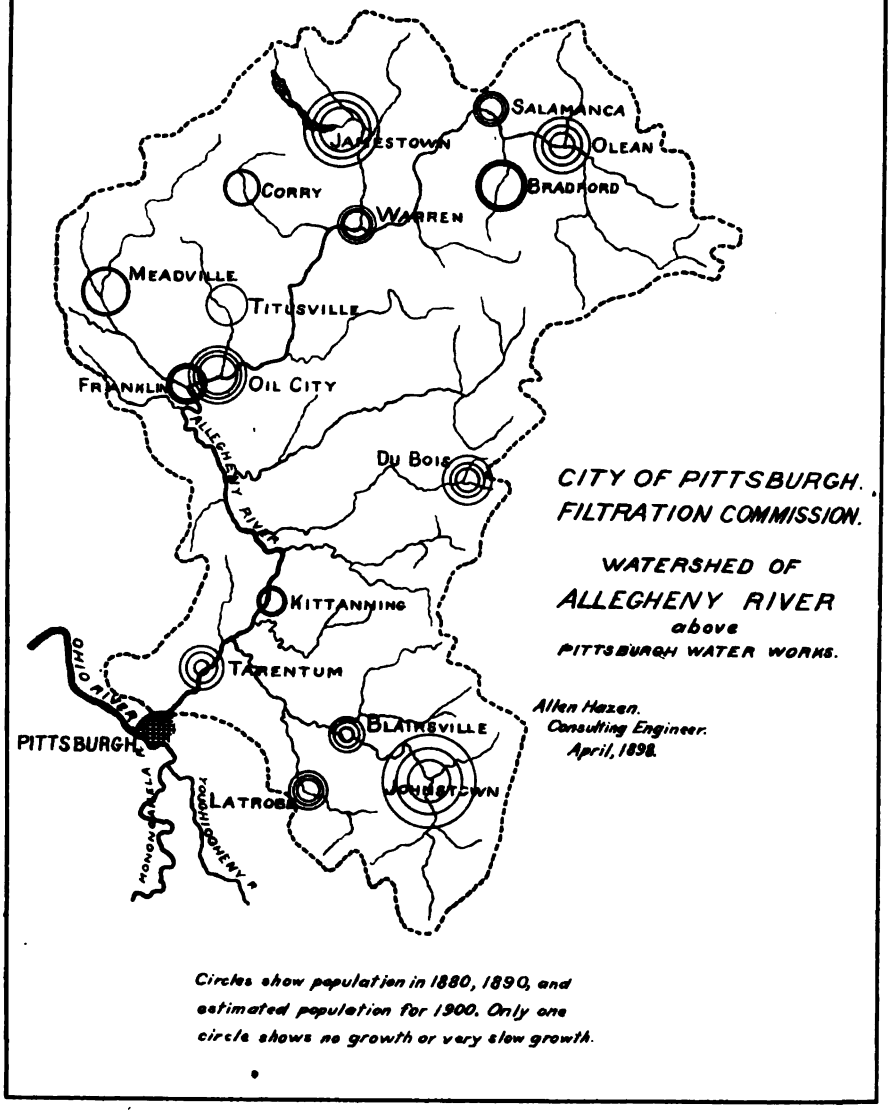
SANITARY CONDITION OF THE PRESENT WATER SUPPLY DRAWN FROM THE ALLEGHENY RIVER.

The Allegheny River at the Brilliant pumping station has a drainage area of about 11,400 square miles. The most important cities and towns upon this drainage area, and their approximate differences from the water works intake, are as follows:—

Cities and Towns upon the Allegheny River and Tributaries above Brilliant Pumping Station.

Place.	Distance in Miles.	Population in 1880.	Population in 1890.	Population in 1900. (Estimated).
Verona	3	1,599	1,497	1,364
Oakmont	4	.....	1,678	1,678
New Kensington	11	.....	.....	.....
Tarentum	14	1,245	4,627	9,254
Freeport	21	1,614	1,637	1,660
Ford City	33	.....	1,255	1,255
Apollo	35	1,156	2,156	4,003
Kittanning	38	2,624	3,095	3,650
Saltsburg	47	855	1,088	1,384
Red Bank	57	.....	.....	.....
East Brady	62	1,242	1,228	1,213
Latrobe	64	1,815	3,589	7,097
Blairsville	65	1,162	3,126	6,252
Derry	72	755	1,968	3,936
Parker	76	1,835	1,317	945
New Bethlehem	77	773	1,026	1,362
Indiana	78	1,907	1,963	2,049
Emlenton	82	1,140	1,126	1,112
Punxsutawney	85	674	2,792	5,584
Johnstown	89	8,380	21,805	43,610
East Conemaugh	92	756	1,158	1,774
Hammerstown	94	.....	1,014	1,014
Brookville	98	2,136	2,478	2,875
South Fork	99	.....	1,295	1,295
Clarion	100	1,169	2,164	4,006
Ebensburg	112	1,123	1,202	1,287
Reynoldsville	112	1,410	2,789	5,504
Franklin	116	5,010	6,221	7,725
Du Bois	121	2,718	6,149	12,298
Oil City	125	7,315	10,932	16,340

Plate No. 3.


SALAMANCA
JAMESTOWN
OLEAN
CORRY
BRADFORD
WARREN
MEADVILLE
TITUSVILLE
FRANKLIN
OIL CITY
ALLEGHENY RIVER
DU BOIS
KITTANNING
OHIO RIVER
TARENTUM
PITTSBURGH
BLAIRSVILLE
JOHNSTOWN
LATROBE
MONONGAHELA
YOUGHIOGHENY R.
CITY OF PITTSBURGH.
FILTRATION COMMISSION.
WATERSHED OF
ALLEGHENY RIVER
above
PITTSBURGH WATER WORKS.
Allen Hazen.
Consulting Engineer.
April, 1898.
Circles show population in 1880, 1890, and estimated population for 1900. Only one circle shows no growth or very slow growth.

Place.	Distance in Miles.	Population in— 1880.	1890.	1900. (Estimated).
Stoneboro	125	1,186	1,394	1,638
Ridgeway	140	1,100	1,903	3,292
Titusville	142	9,046	8,073	7,205
Meadville	144	8,860	9,520	10,229
St. Marys	148	1,501	1,745	2,029
Johnsonburg	149	.....	1,280	1,280
Wilcox	151	.....	1,037	1,037
Tidioute	160	1,255	1,328	1,405
Edenboro	161	876	1,107	1,399
Waterford	170	.....	.....	.....
Sheffield	172	684	1,295	2,452
Union	177	2,171	2,216	2,262
Clarendon	180	295	1,297	2,594
Warren	181	2,810	4,332	6,678
Corry	195	5,277	5,677	6,108
Busti, N. Y.	205	1,901	2,089	2,296
Jamestown, N. Y.	210	9,357	16,038	27,489
Randolph, N. Y.	212	1,111	1,201	1,298
Salamanca, N. Y.	222	2,531	3,692	5,386
Mayville, N. Y.	227	1,051	1,164	1,289
Bradford	240	9,197	10,514	12,010
Kendall	240	2,689	1,937	1,395
Olean, N. Y.	241	3,036	7,358	14,716
Cuba, N. Y.	256	1,251	1,386	1,536
Franklin, N Y.	258	672	1,021	1,551
Eldred	263	1,165	1,050	946
Port Allegheny	266	731	1,230	2,070
Smethport	267	872	1,150	1,517
Coudersport	282	667	1,530	3,060
Total urban population		121,705	185,939	277,693
Urban population per square mile,		11	16	24

Of the above towns it is fair to assume that only the larger ones are yet sewered, and that the population contributing sewage to the river is only a fraction of the total as given. The populations are increasing rapidly, however, and the use of sewers even more rapidly, so that the amount of polluting matter entering the river, already considerable, is sure to increase rapidly.

As compared with other rivers used for municipal supplies in this country and in Europe, the urban population is comparatively small, and

most of it is far removed from the present intake. The effect of this population upon the healthfulness of the source of supply is discussed at length by Professor Sedgwick, in his report upon this subject.

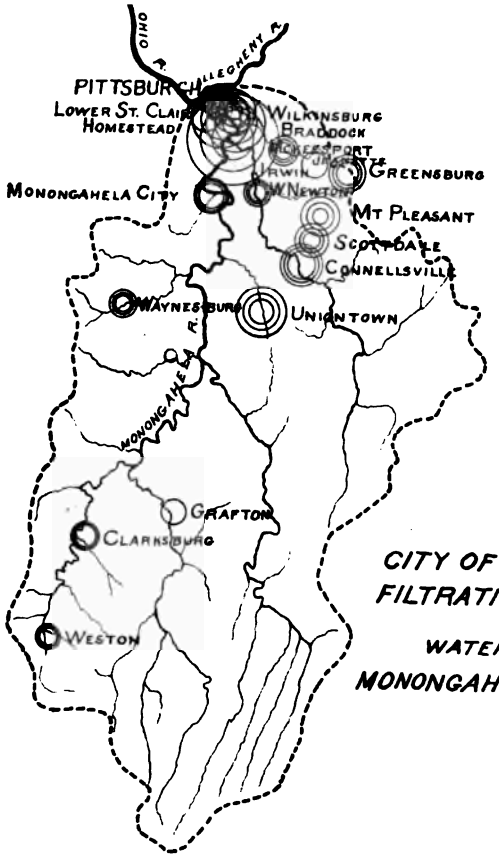
SANITARY CONDITION OF THE WATER SUPPLIED TO THE SOUTH SIDE FROM THE MONONGAHELA RIVER.

As a considerable part of the city of Pittsburgh is supplied from the Monongahela River, investigations have been made of the quality of the water supplied. The drainage area above the intake of the Monongahela Water Company is about 7,600 square miles. The most important cities and towns upon this drainage-area are as follows:—

Cities and Towns upon the Monongahela River and Tributaries above Intake of Monongahela Water Company.

Place.	Distance in Miles.	Population in— 1880.	1890.	1900. (Estimated).
Lower St. Clair	3	.....	4,303	4,303
Homestead	6	592	7,911	15,822
Braddock	9	3,310	8,561	17,122
Wilkinsburg	9	1,529	4,662	9,324
Port Perry	11	1,100	1,031	966
Turtle Creek	12	.....	.....	.....
Wilmerding	13	.....	419	419
McKeesport	14	8,212	20,741	41,482
Elizabeth	20	1,810	1,804	1,798
Irwin	23	1,444	2,428	4,070
Jeannette	29	.....	3,296	3,296
Monongahela City	29	2,904	4,096	5,777
West Newton	32	1,475	2,285	3,539
Greensburg	33	2,500	4,202	7,063
Belle Vernon	41	1,164	1,147	1,130
Everson	50	.....	.....	.....
Scottdale	52	1,275	2,693	5,688
Brownsville	52	1,489	1,417	1,352
Bridgeport	55	1,134	1,030	927
Mt. Pleasant	57	1,197	3,652	7,304
New Haven	57	442	1,221	2,442
Connellsville	57	3,609	5,629	8,780
Dunbar	61	.....	1,381	1,381
Uniontown	69	3,265	6,359	12,380
Waynesburg	80	1,208	2,101	3,654

Plate No. 4.



CITY OF PITTSBURGH
FILTRATION COMMISSION

WATERSHED OF
MONONGAHELA RIVER

Allen Hazen
Consulting Engineer.
Dec. 1898.

Circles show population in 1880, 1890, and estimated population for 1900. Only one circle shows no growth or very slow growth.

Place.	Distance in Miles.	Population in— 1880.	1890.	1900. (Estimated).
Fairchance	95	.....	1,092	1,092
Morgantown, W. Va.	95	745	1,011	1,372
Somerset	112	1,179	1,713	2,489
Meyersdale	112	1,423	1,847	2,397
Fairmount, W. Va.	120	900	1,023	1,163
Grafton, W. Va.	140	3,030	3,159	3,294
Clarksburg, W. Va.	150	2,307	3,008	3,922
Weston, W. Va.	180	1,516	2,143	3,030
Buckhannon, W. Va.	180	761	1,403	2,587
Total urban population		51,520	108,768	181,365
Urban population per square mile,		7	14	24

The urban population per square mile upon the Monongahela River is equal to that upon the Allegheny. There is this important difference, however, that while most of the urban population upon the Allegheny is at points far away from the water intake, that upon the Monongahela is largely concentrated within a comparatively short distance from the intake. The Monongahela River also receives a much larger amount of mine drainage than the Allegheny, and this mine drainage affects and greatly increases the mineral matter contained in it. During the year ending July 31, 1898, the average compositions of the two rivers were as follows:—

	Monongahela.	Allegheny.
Turbidity	(Results incomplete)	0.17
Color	0.20	0.29
Alkalinity	1.35	2.87
Solids	20.08	15.6
Suspended Matter	6.3	3.9
Hardness	4.40	3.55
Chlorine	1.18	2.17
Sulphuric Acid	4.00	1.48
Iron	0.0966	0.0543
Free Ammonia	0.0066	0.0019
Albuminoid Ammonia	0.0149	0.0117
Nitrates	0.0880	0.0705
Nitrites	0.0000	0.0000
Bacteria	22,833	17,314

These results are taken for the calendar year. Our examinations have extended over a somewhat longer period, but averaging the whole time would include two summer or low water periods, and only one

spring or high water period, and would obviously not give representative results.

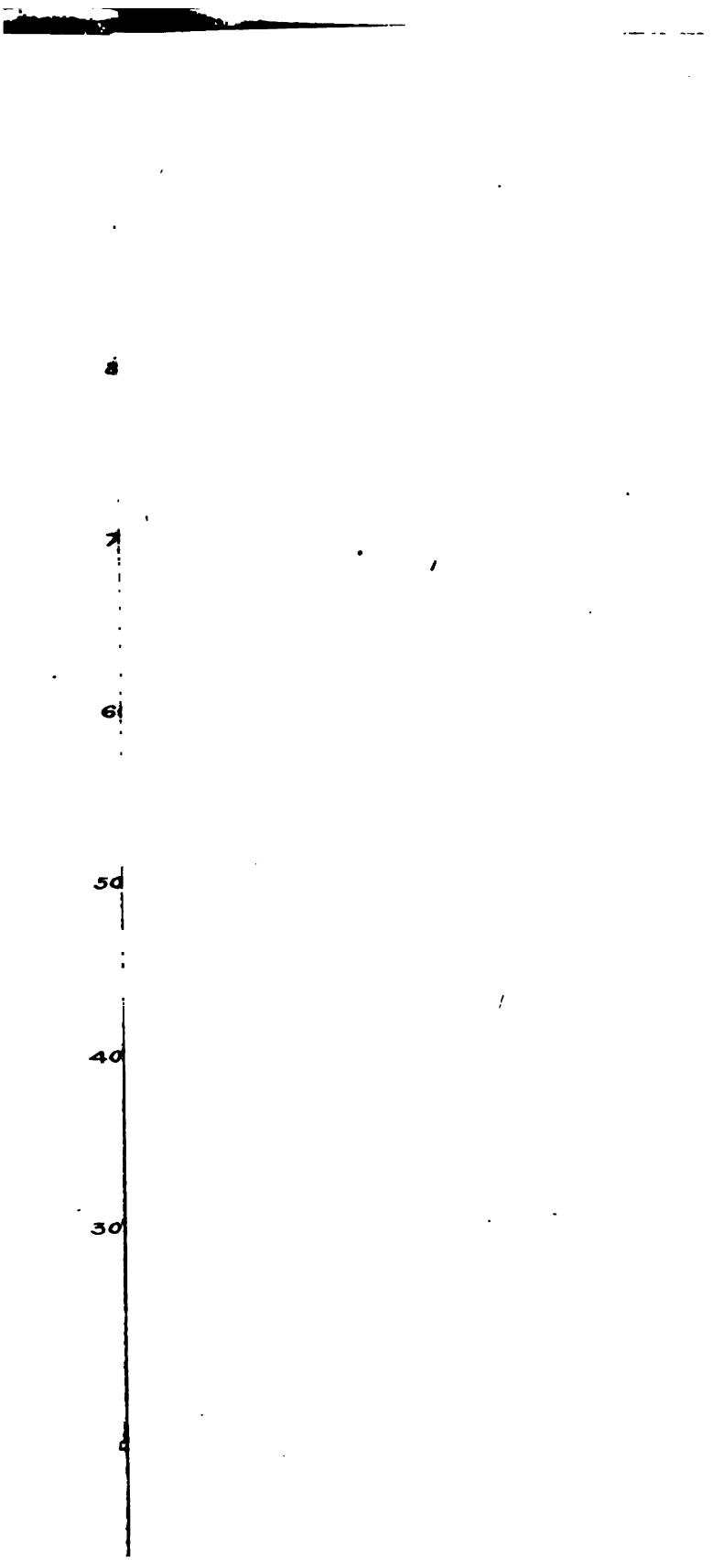
It will be seen from this comparison that the water of the Monongahela carries more suspended matter, is harder, and contains more organic matter and more bacteria than the water of the Allegheny. Its alkalinity is very much less, owing to the presence of a larger amount of acid mine drainage. The Monongahela River is said to become acid at times, although it has not done so during the period covered by our analyses.

From every standpoint the water of the Allegheny is more desirable for a municipal water supply than that of the Monongahela, and we have considered it probable that the present supply for the South Side, now drawn from the Monongahela, would ultimately be abandoned, and that the Allegheny River supply would be extended to this portion of the city.

MUDDINESS.

The water of the Allegheny River is always more or less turbid; occasionally it becomes very muddy. The water is pumped from the river to distributing reservoirs, where a part of the suspended matter is removed by sedimentation. Even with this sediment removed, the water as supplied is very often so muddy as to be seriously objectionable to those who use it.

A record has been kept since the commencement of our work of the muddiness of the river water. To measure the turbidity or muddiness of water a platinum wire is fastened to a long stick and is sunk into the water as far as the wire can be seen. At the point where the wire is just ready to disappear from view its depth below the surface is measured, and the depth forms a measure of the muddiness of the water. For convenience the muddiness is recorded as the reciprocal of the depth at which the wire can be seen in inches. During continued dry weather with very low water the turbidity falls to 0.03, with the wire visible 33 inches below the surface. After summer rains the turbidity is increased water stages a turbidity of 0.10 is common, with the wire visible ten inches below the surface. After summer rains the turbidity is increased to 0.20 to 0.50, with the wire visible from five to two inches. Heavy rains result in turbidities of 1.00, with the wire visible one inch below the surface, and this may be considered as the ordinary maximum turbidity of the river. On three occasions has this turbidity been exceeded; namely, March 23, when with the highest freshet this year, the turbidity rose to 2.38, with the wire visible less than half an inch from the surface; on May 17, when the turbidity rose to 1.20; and on August 20, when a turbidity of 1.75 was observed. The following is a tabular statement


8
7
6
5
40
30

of the number of days on which the various turbidities were observed in the water of the Allegheny River at the Brilliant pumping station, for the year ending July 31, 1898:—

Turbidities.	Number of Days.	Percentage of Total Number of Days.
Above 1.00	2	0.5
0.51 to 1.00	21	5.8
0.21 to 0.50	51	14.0
0.11 to 0.20	64	17.5
0.06 to 0.10	94	25.7
0.02 to 0.05	133	36.5
	365	100.0

Average turbidity, 0.17.

It was at first thought that the turbidities bore a relation to the height of the river, and that this relation could be established from the records of this year and applied to the records of river heights for previous years, and in this way an approximate computation of turbidities extending over a longer period could be made. It was found, however, upon comparing the turbidities and river heights that no definite relation could be established. Occasionally a sharp but not high rise of the river is followed by a very high turbidity, while on the other hand, a very much higher rise under other conditions is accompanied by less muddy water.

As the condition of the river depends more or less directly upon the meteorological conditions, the records of monthly precipitations and temperatures have been secured for the past ten years and plotted. These plottings are presented herewith.* The conditions during the period covered by our experiments are shown by heavy lines and the corresponding conditions for other years dotted lines. It will be seen that March, 1898, was exceptionally warm, and April exceptionally cold. Both July and August were warmer than the average, although not reaching the highest record for monthly heat. October, 1897, was also a warm month. The winter was not exceptionally severe, although February was colder than the average.

The precipitation was exceptionally heavy in November, 1897, and March, 1898, and exceptionally low in September and October, 1897. On the whole, both precipitation and temperature records are essentially normal, and present about the same range as has been common during the last ten years. It is perhaps a fair deduction that our record of turbidities extending over more than a year affords a good idea of the general condition of the river for a period of years, and we have no reason

* See Plate No. 5, opposite Page 34, and Plate No. 6, opposite Page 36.

to believe that the condition of the river during this period has been other than essentially normal.

The presence of this mud in the water is a source of serious inconvenience and discomfort to the people using it, and is objectionable in many mechanical operations for which the water is used. To remove this mud is one of the most important objects to be reached by filtration, and has been carefully considered in all our investigations.

NATURE OF FILTRATION.

The filtration of water consists in passing it through some substance which retains and removes the suspended matters contained therein. Under certain conditions matters in solution are also removed. In sand filtration as practiced in Europe for many years, and in this country on a less extensive scale, the water is passed through sand contained in large masonry basins, at a rate not exceeding, in general, five vertical inches per hour, or three million gallons per acre daily, although somewhat higher rates are occasionally used. The filtered water is removed from below through underdrains surrounded by gravel. Filters are constructed in sections so that parts can be put out of service and cleaned while other sections are furnishing the supply. This method of filtration is used for filtering the water supplied to cities with an aggregate population of over twenty millions of people.

In mechanical filtration the rate at which water is passed through the sand is increased many times, commonly to 150 to 200 vertical inches per hour. The efficiency of filtration is, in general, inversely proportional to the rate, and purification of water at such rates would be impossible were it not for the introduction of other factors. The element relied upon in mechanical filtration to allow satisfactory results to be obtained at high rates is alum, or sulphate of alumina. This chemical is added to the water to be filtered and is decomposed into its component parts,—alumina and sulphuric acid. The sulphuric acid remains in the water, while the alumina forms a gelatinous precipitate which surrounds and entangles the fine suspended particles in the water and allows them to be removed much more readily than would otherwise be the case. Objection has been raised to the use of alum on hygienic grounds, but when due care is exercised in its use, it is doubtful if it is ever really injurious to health. Water usually contains sufficient lime to combine with the sulphuric acid, forming the comparatively harmless sulphate of lime, while nearly all of the alumina is removed in the process of filtration, and it is not clear that it is injurious to health, even if an extremely small quantity is found in the effluent.

8 in.
6 in.
4 in.
2 in.
0

EXPERIMENTS UPON FILTRATION.

There have been installed and operated at the Brilliant pumping station one sedimentation basin, two sand filters, one Jewell mechanical filter, one Warren mechanical filter, and also a set of artificial sandstone tiles on the Fischer system. It was not the object of these experiments to settle all questions in regard to filtration which might be raised, but rather to determine the power of sand filters to deal with water as muddy as that of the Allegheny, and to ascertain what bacterial efficiencies could be secured by mechanical filtration, and to afford information on some purely local problems. These experiments also served as practical demonstrations of the results obtained by the different processes, and afford a basis for direct comparisons between them, each operated under as favorable conditions as could be secured.

With the sand filters it was assumed that the kind of sand to be employed, the depth of sand, the limit to the loss of head, the rate of filtration, and the general arrangement and operation of the plant were sufficiently well known from experiments made elsewhere and from general practice; and the filters were constructed to represent what might be considered the best practice in these respects, and no attempt has been made to investigate them. It was intended, however, to secure data upon the following points:—

1. Whether the Allegheny River water could be successfully filtered without preliminary sedimentation, and whether such sedimentation was desirable.

2. Whether it would be necessary or desirable to cover filters for use in the climate of Pittsburgh.

3. To determine whether or not the mud, crude petroleum, mine drainage, and other substances present in the Allegheny River water would interfere with the work of filtration, and cause results to be obtained materially different from those which have been obtained elsewhere.

4. To determine the frequency with which it would be necessary to clean filters, both with and without preliminary sedimentation, this information being necessary to a computation of the cost of operation.

With regard to mechanical filters, it was assumed that the filters used represented the most perfect types of mechanical filters yet constructed, and that the results obtained with them could be regarded as representing the best obtainable results under these processes. The questions presented in connection with them were whether or not effluents could be obtained equal in bacterial purity to those obtained from sand filters, or if not equal, at least of satisfactory quality; and second, to determine what quantity of coagulant would be required to accomplish satisfactory results at various river stages.

RESULTS FROM EXPERIMENTAL FILTERS.

The work of installing and operating experimental filters was placed in charge of Mr. Morris Knowles, Resident Engineer of the Commission, who has made a report, giving in detail descriptions of the work thus done, which report is hereto appended. The biological examinations were made by Mr. William R. Copeland, Bacteriologist of the Commission, who was provided with a temporary laboratory near the filters, and who also gave his personal attention to many matters connected with their operation. Chemical analyses were made by Dr. Walther Riddle, Chemist of the Commission. Both Mr. Copeland and Dr. Riddle have made reports upon the methods employed by them, which reports are hereto appended. Full tabular statements of the daily results from each of the filters are given in Mr. Knowles' report. For convenience a summary of the monthly results is here presented.

Summary of Results from Sand Filters by Months.

Month,	Turbidity of Raw Water.	BACTERIA PER CUBIC CENTIMETER. Raw Water.	Settled Water.	Effluents. No. 1.	No. 2.	BACTERIAL EFFICIENCY, PER CENT. No. 1.	No. 2.	NET YIELD OF FILTERS IN MILLION GALLONS PER ACRE DAILY. No. 1.	No. 2.
1897.									
August....	0.19	2,089	1,283	46	42	97.80	97.99	2.40	2.30
September..	0.05	2,478	1,231	16	16	99.35	99.35	2.98	3.00
October....	0.04	72,878	39,186	32	32	99.96	99.96	2.90	2.95
November..	0.24	25,220	29,924	346	632	98.63	97.49	2.64	2.42
December..	0.19	14,433	14,923	163	225	98.87	98.44	2.76	2.46
1898.									
January....	0.27	15,333	13,828	334	310	97.82	97.98	2.77	1.87
February..	0.15	9,430	12,043	266	275	97.18	97.08	2.93	2.27
March.....	0.30	11,747	12,347	71	332	99.40	97.17	2.95	2.83
April.....	0.08	5,010	4,298	33	91	99.34	98.18	2.95	2.99
May.....	0.19	10,800	6,770	110	99	98.98	99.08	2.93	2.95
June.....	0.19	11,100	5,930	135	72	98.78	99.35	2.83	2.85
July.....	0.11	16,800	13,000	74	89	99.56	99.47	2.94	4.97
August....	0.36	15,100	10,250	51	82	99.66	99.46	2.85	4.82
Averages...	0.18	16,340	12,693	129	177	99.21	98.92	2.83	2.98

Note :—No. 2 was operated with raw or unsettled water from July 24 to December 19, and from February 20 to June 30, otherwise settled water was applied to both filters.

Composition of Allegheny River Water Before and After Settling and After Passing Through Sand Filters, for the Thirteen Months, Ending August, 1898.

	River Sample.	Gate Chamber Sample.	After Passing Settling Basin.	Effluents. No. 1.	No. 2.
Color	0.29	0.29	0.27	0.09	0.09
Alkalinity	2.89	3.05	3.07	4.13	4.22
Total Solids	15.9	15.5	13.1	12.1	12.1
Suspended Matter	4.2	3.9	1.3	0.0	0.0
Hardness	3.58	3.67	3.69	4.72	4.83
Chlorine	2.19	1.99	2.08	2.06	2.02
Sulphuric Acid	1.44	1.47	1.38	1.44	1.44
Iron	0.0516	0.0724	0.0605	0.0160	0.0179
NITROGEN AS,—					
Free Ammonia	0.0019	0.0019	0.0019	0.0016	0.0016
Albuminoid Ammonia	0.0116	0.0115	0.0108	0.0063	0.0064
Nitrates	0.0684	0.0665	0.0641	0.0715	0.0647
Nitrites	0.0000	0.0000	0.0000	0.0000	0.0000
Bacteria	17,405	16,314	12,663	129	176

Summary of Results from Mechanical Filters by Months.

GENERAL SUMMARY,—WARREN FILTER.

Month,—1898.	Turbidity of Raw Water.	BACTERIA PER CUBIC CENTIMETER. River Water.	Effluent.	Bacterial Efficiency, Per Cent.	Sulphate of Alumina, Grains per Gallon.	Wash and Waste, Per Cent.	Rate of Filtration, Million Gallons Per Acre Daily; When in Service.
February	0.15	9,430	238	97.48	0.70	5.3	104
March	0.30	11,747	164	98.60	1,81	4.8	108
April	0.08	5,010	78	98.44	0.86	3.7	122
May	0.19	10,800	630	94.20	1.55	3.4	115
June	0.19	11,100	115	98.96	1.36	5.1	103
July	0.11	16,800	320	98.10	1.46	6.5	119
August	0.36	15,100	290	98.08	1.76	6.4	137
Averages	0.20	11,427	262	97.70	1.36	5.0	115

Note:—Special experiments were made during May. Excluding May, average bacterial results were; raw water, 11,531; effluent, 201; bacterial efficiency, 98.26 per cent.

GENERAL SUMMARY,—JEWELL FILTER.

February	0.15	9,430	638	93.23	0.56	6.1	98
March	0.30	11,747	208	98.23	1.07	4.3	106
April	0.08	5,010	159	96.83	0.54	2.8	106
May	0.19	10,800	150	98.61	1.01	4.6	106
June	0.19	11,100	1,450	86.90	1.18	5.4	106
July	0.11	16,800	345	97.95	1.31	7.6	103
August	0.36	15,100	260	98.28	1.35	6.3	103
Averages	0.20	11,427	459	95.99	1.00	5.3	104

Note:—Special experiments were made during June. Excluding June, average bacterial results were; raw water, 11 481; effluent, 293; bacterial efficiency, 97.45 per cent.

WATER QUANTITIES,—WARREN FILTER.

Month,—1898.	Entering Water.	Waste Before Filtration.	Water Filtered.	Filtered Water Used for Washing.	Net Available Yield for Supply.	Hours in Service.	Rate of Filtration, Million Gallons Per Acre Daily, When in Service.	Net Supply, Per Square Foot of Filter, Daily, in Gallons.
	Thousands of Gallons.							
January	1,896	34	1,862	89	1,773	141.6	115	.....
February	7,113	108	7,005	266	6,739	597.2	104	2,031
March	8,583	115	8,468	294	8,174	691.4	108	2,235
April	9,658	103	9,555	246	9,309	690.7	122	2,628
May	9,519	79	9,440	248	9,192	730.6	115	2,512
June	8,265	98	8,167	320	7,847	699.0	103	2,224
July	8,239	115	8,124	418	7,706	603.9	119	2,107
August	11,306	144	11,162	571	10,591	719.5	138	2,895
Totals	64,579	796	63,783	2,452	61,331	4,873.9	...	.....
Averages	...	...	.....	.....	.....	.....	116	2,381

WATER QUANTITIES,—JEWELL FILTER.

January	599	...	599	53	546	64.7	85	.....
February	6,139	...	6,139	372	5,767	580.7	98	1,822
March	7,875	...	7,875	339	7,536	688.7	106	2,151
April	7,858	...	7,858	224	7,634	687.7	106	2,251
May	8,246	...	8,246	378	7,868	720.6	106	2,246
June	7,834	...	7,834	424	7,410	684.2	106	2,186
July	7,638	...	7,638	577	7,061	687.3	103	2,016
August	7,912	...	7,912	500	7,412	708.7	103	2,116
Totals	54,101	...	54,101	2,867	51,234	4,822.6	...	.....
Averages	...	...	.....	.....	.....	.....	102	2,111

WASH WATER,—WARREN FILTER.

Month,—1898.	Number of Times Washed.	Number of Minutes.	Gallons Per Minute.	Gallons Per Minute Per Square Foot of Filter Area.	Average Quantity Filtered Between Washings. Thousand Gals.	Million Gallons Per Acre.	Per Cent. of Wash.	Per Cent. of Waste.
January	14	195	456	3.9	134	50	4.8	1.8
February	45	499	533	4.5	156	58	3.8	1.5
March	48	383	678	6.5	177	65	3.5	1.3
April	43	307	801	6.8	222	82	2.6	1.1
May	33	332	747	6.3	280	106	2.6	0.8
June	41	412	777	6.6	200	74	3.9	1.2
July	48	521	802	6.8	170	64	5.1	1.4
August	60	659	866	7.3	186	69	5.1	1.3
Totals	332	3,308	...	...	...	..	...	...
Averages	.....	.....	741	6.3	192	71	3.8	1.2

WASH WATER,—JEWELL FILTER.

January	8	131	405	3.6	75	29	8.8	...
February	69	744	500	4.4	89	34	6.1	...
March	75	519	653	5.8	105	40	4.3	...
April	49	301	744	6.6	160	62	2.8	...
May	72	508	744	6.6	115	44	4.6	...
June	69	572	741	6.6	114	44	5.4	...
July	84	765	754	6.7	91	35	7.6	...
August	61	625	800	7.1	130	50	6.3	...
Totals	487	4,165	...	...	...	..	...	...
Averages	.....	.....	689	6.1	111	42	5.3	...

SULPHATE OF ALUMINA,—WARREN FILTER.

Month, 1898.	Pounds Used During Month.	Grains per Gallon Computed on Quantity of Water Treated.	Water Filtered.	Net Supply.
January	316	1.17	1.19	1.25
February	701	0.69	0.70	0.74
March	2,183	1.78	1.81	1.87
April	1,166	0.85	0.86	0.88
May	2,100	1.51	1.55	1.60
June	1,587	1.34	1.36	1.42
July	1,692	1.43	1.46	1.54
August	2,798	1.73	1.76	1.85
Total	12,543	....	....	....
Averages		1.36	1.38	1.44

SULPHATE OF ALUMINA,—JEWELL FILTER.

January	62	0.72	0.72	0.80
February	489	0.56	0.56	0.59
March	1,204	1.07	1.07	1.12
April	610	0.54	0.54	0.56
May	1,182	1.01	1.01	1.05
June	1,324	1.18	1.18	1.25
July	1,423	1.31	1.31	1.41
August	1,521	1.35	1.35	1.44
Total	7,815	....	....	....
Averages		1.01	1.01	1.07

Composition of Allegheny River Water Before and After Passing Mechanical Filters, for the Seven Months, Ending August, 1898, with Results from Sand Filters for the Same Period.

	Allegheny River.		Mechan'l Filters. Effluents.		Sand Filters.		
	River Sample.	Gate Chamber Sample.	Warren Filter.	Jewell Filter.	Settling Basin.	Effluents. No. 1.	No. 2.
Turbidity		0.20	0.004*	0.002*	0.14	0.010	0.012
Color	0.26	0.26	0.03	0.03	0.24	0.07	0.07
Alkalinity	2.44	2.56	1.61	1.72	2.49	3.53	3.56
Solids	15.4	15.0	9.3	9.5	11.9	10.8	10.6
Suspended	5.3	4.9	0.0	0.0	1.7	0.0	0.0
Hardness	3.21	3.31	2.92	3.03	3.27	4.31	4.33
Chlorine	1.87	1.73	1.71	1.71	1.80	1.84	1.77
Sulphuric Acid	1.15	1.17	1.80	1.67	1.10	1.15	1.15
Iron	0.0320	0.0448	0.0058	0.0053	0.0373	0.0111	0.0145
Nitrogen as,—							
Free Ammonia	0.0020	0.0022	0.0019	0.0018	0.0020	0.0018	0.0018
Albuminoid Am'nia	0.0101	0.0100	0.0047	0.0044	0.0092	0.0054	0.0053
Nitrates	0.0568	0.0611	0.0512	0.0491	0.0581	0.0642	0.0549
Nitrites	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Bacteria	11,337	11,258	201*	293*	9,224	106	148

* Excluding inferior results obtained during special experiments.

RESULTS WITH SAND FILTERS.

Necessity of Preliminary Sedimentation.

Two sand filters were constructed and one sedimentation basin. One filter was supplied with the water as pumped from the river, and the other with similar water after passing through the sedimentation basin. During the first three months of their use the river water had uniformly low turbidities, and the filters gave equally good results in all respects. Afterwards turbid waters were obtained from the river more frequently, and with the appearance of the greater turbidities a marked difference in the behavior of the two filters was observed. The filter supplied with settled water operated for longer periods between cleanings, and gave a much more satisfactory effluent than that supplied with raw water. At times of maximum turbidity the filter supplied with unsettled water became clogged so rapidly that grave difficulties would be experienced in cleaning filters in a municipal plant operated in this manner. The bacterial efficiency was also materially less than that of the filter receiving settled water, although the settling itself removed but few of the bacteria. The experiments thus demonstrated that for the Allegheny River water preliminary sedimentation, if not absolutely necessary, is certainly desirable, and either that or its equivalent must be considered as an essential part of a filtration plant.

Necessity of Covering Filters.

In severe climates it is necessary to cover filters as a protection against frosts. In warmer climates this is unnecessary. In Europe it has been found that in those cities where the winters are so severe that the normal January temperature is below 32 degrees, Fahrenheit, it is generally necessary to cover filters as a protection against frost, while in places where the winters are less severe, covers are unnecessary. American experience is as yet somewhat limited, but the experience with open filters at Lawrence and Poughkeepsie has indicated that for America also the above statement is approximately correct.

There are apparent exceptions to this rule in several cases where raw water is drawn from deep reservoirs or wells, and has always a temperature somewhat above the freezing point. In these cases open filters operate successfully in colder climates than the above limit.

The normal January temperature at Pittsburgh is about 32°, and is so close to the limit as to leave it uncertain whether covers are necessary or desirable. To throw light upon this subject our experimental filters were left open, and were operated throughout the winter without protection from cold. Their efficiencies during the period of greatest cold fell materially below the efficiencies obtained at other periods of

the year. The decrease in efficiency was greatest in the filter receiving raw water; but as sedimentation basins are considered as a necessary part of a sand filtration plant for Pittsburgh, we may confine our attention to the results obtained from the filter receiving settled water.

The bacterial efficiency in September and October, and the early part of November, was exceptionally high. The monthly average for November shows a drop to 98.58, but this decrease was due to a defect in the construction of the filter, which is described in detail in the report of the Resident Engineer. Excluding the results for one week, the bacterial efficiency for November was 99.44 per cent., which is quite normal. In December the bacterial efficiency fell to 98.88; in January to 97.82; and in February, which was the coldest month of the season, to 97.18. Afterwards the efficiency rapidly improved, and remained at about or above 99 per cent. for the remainder of the time covered by our experiments.

It will thus be seen that while the efficiency for the winter months was less than at other times, it did not fall below an average of 97 per cent.; and it may be that this efficiency will be satisfactory for the conditions at Pittsburgh. It is probable, further, that in an actual plant, by improved manipulation, the reduction in efficiency will be less than it was in the experimental plant, although sometimes colder weather would occur than any during the past winter.

The most important point to be observed in operating filters in winter is to clean the filters in weather that is not too cold, and to prevent the sand from freezing while exposed to the air. The experimental filters were always cleaned when they became clogged, or directly afterward, and the sand became frozen on several occasions, with the result of decreasing the efficiency as above shown. With a sufficient reserve area it would be possible generally to wait for a few days, if necessary, for warmer weather before cleaning, and consequently there would be less disturbance in the normal action of the filters. The experimental filters were kept up to their nominal delivery regardless of the weather.

The winter disturbances can, if necessary, be entirely eliminated by the construction of covered filters at an additional expense as stated in connection with the estimates of cost; but I do not regard this as necessary, and do not recommend it.

Effect of the Mud, Crude Petroleum, Mine Waste, etc., upon Sand Filters.

The Allegheny River receives at times a great deal of crude petroleum and coal-mine waste. These substances are not generally present in other river waters which have been successfully filtered. It was thought that these substances might have some effect upon the operation of the

filters which would materially influence the results obtained. In the course of our experiments no such disturbing action has been present.

The effect of excessive quantities of mud in the raw water has been generally recognized. The most obvious effect is to shorten the period between scrapings, making cleanings more frequent and expensive. It is also noticed that when the turbidity of the water applied to the filters is very high some of it passes through the filter, and turbid effluents result. This is particularly the case at high rates of filtration.

During the months of July and August, 1898, Filter No. 2 was operated at a rate of five million gallons per acre daily. During a part of this time the river water was very muddy, and the effluent from the filter operating at the five-million rate became four times as turbid as that operating at a three million rate. The turbidity of the effluent at the five million rate reached 0.07, a point which would be seriously objectionable to the water takers. The highest turbidity reached at this time with the filter operated at the three million rate was 0.02, a turbidity which is just visible in an ordinary drinking glass, and which would not be seriously objectionable to any one.

At the time of the spring freshets, with very high and continued turbidities in the raw water, when filtering at a three million rate, effluents with turbidities of from 0.03 to 0.06 were obtained for four days. It is believed, however, that in practice filters could be so operated as never to produce effluents of this degree of turbidity. Owing to the fact that the consumption at such times is generally less than the average, there is a large reserve filtering area and somewhat lower rates of filtration could be employed. Further, the quantity of water stored in the system of reservoirs is considerable, and could be safely drawn upon for part of the supply for the short periods at which these very high turbidities occur. By reducing the rate of filtration somewhat at these times, it is believed that the turbidity can always be kept within limits which will not be objectionable to any one.

Frequency of Scraping Sand Filters.

Filter No. 1, receiving settled water, was scraped during the period covered by our experiments fourteen times. The quantities of water passed between scrapings and the depth of sand removed were as follows:

Date. 1897.	Number of Period.	Quantity of Water Filtered, Million Gallons Per Acre.	Depth of Sand Removed in Feet.	Average Turbidity of Applied Water.
July 24 to August 17.....	1	45.0	0.04	0.20
August 18 to October 9.....	2	136.0	0.06	0.06
October 10 to November 11.....	3	104.2	0.05	0.03
November 18 to December 8.....	4	61.7	0.05	0.21
December 9 to December 28....	5	56.1	0.13	0.15
1898.				
December 30 to January 11.....	6	38.4	0.03	0.08
January 12 to January 25.....	7	38.5	0.05	0.21
January 26 to February 7.....	8	35.2	0.10	0.10
February 8 to March 10.....	9	91.3	0.07	0.10
March 11 to April 7.....10		80.1	0.12	0.12
April 8 to May 10.....11		102.3	0.07	0.06
May 11 to June 16.....12		102.9	0.07	0.10
June 17 to July 18.....13		94.0	0.09	0.13
July 19 to August 19.....14		94.3	0.13	0.21
Averages		77.1	0.076	....

The loss of head was, in general, limited to about four feet. In the first two periods the loss of head was allowed to reach a considerably higher figure, and in these cases only the quantities have been taken which were filtered before the loss of head reached four feet. The average quantity of water filtered between scrapings was 77,000,000 gallons per acre with a loss of head of four feet.

Filter No. 2 was operated for about nine months with raw water and four months with settled water, and the average period was 57,000,000 gallons per acre filtered between scrapings. This result, however, is of no value for the purpose of our computations, as the procedure adopted was not that which would be adopted in a municipal plant.

The period obtained with No. 1 is rather higher than the average of German results, and is about the same as the average period of the London Water Companies. It is somewhat greater than has been obtained at Lawrence, Mass., with the Merrimac River water, and about the same as that obtained at Mount Vernon and Poughkeepsie, N. Y. The German results are low because the loss of head is limited in general to about two feet instead of the four feet used at Pittsburgh, and the Lawrence results are low owing to the peculiar construction of the filter. At Pittsburgh the

results indicate that the cost of operation of filters will be quite as moderate as compared with the costs in other places.

RESULTS WITH MECHANICAL FILTERS.

The principal problem to be solved in connection with mechanical filtration was to determine the bacterial efficiency which could be secured and the conditions which control it. The filters were not put in operation until January, 1898, owing to various delays in the arrangements with the mechanical filter companies and in the manufacture of the apparatus, over which we had no control. The filters were in good working order by the first of February, and the monthly results from that date are given in the above table.* In general the filters were operated in accordance with suggestions of the filter companies, and in such a manner as to give the best possible effluents obtainable under ordinary working conditions.

It soon became apparent that the amount of sulphate of alumina employed was more important than any other factor in determining the bacterial efficiency, and it was thus important to establish the effect of more and of less coagulant than was used in the ordinary daily work. Special experiments in this direction were made upon the Warren Filter during May, and with the Jewell Filter during June. The monthly averages for these months are thus abnormal, and are not to be considered. The remaining six months may be taken as normal and as representing approximately the work of these filters under ordinary careful working conditions.

During the six months when the Warren Filter was in normal order the raw water contained 11,531 bacteria and the effluent 201, the average efficiency being 98.26 per cent. The bacterial efficiency was very constant, ranging only, by months, from 97.48 to 98.96 per cent. During the same months Sand Filter No. 1 yielded an effluent having 105 bacteria per cubic centimeter, or one-half as many as the water from the mechanical filter. This period for Filter No. 1 included the month of February, which was the month when the greatest decrease in efficiency from cold was observed.

The Jewell Filter, for the six months in which it was in normal order, received raw water containing an average of 11,481 bacteria, and yielded an effluent containing an average of 293, the bacterial efficiency being 97.45 per cent., and ranging, in different months, from 93.23 to 98.61 per cent. Sand Filter No. 1 for the same months yielded an effluent containing 101 bacteria per cubic centimeter, or a little more than one-third as many as the effluent from the Jewell Filter. The number of bacteria

* See Page 40.

passing the mechanical filters was thus on an average two or three times as great as the number passing the sand filters.

Wasting Effluent after Washing Filters.

After washing a mechanical filter the effluent for the first few minutes is often inferior in quality to that obtained at other times, and if samples are taken at these times and averaged with other samples taken during the run, an apparent efficiency may be obtained inferior to the true efficiency. To guard against this source of error, whenever samples have been taken at such times, the average work for the day has been taken not as the numerical average of the results, but each sample has been given weight in proportion to the amount of time which it could be taken as representing; so that the results represent as nearly as possible the average number of bacteria in the effluent for the whole run. As a matter of fact, however, comparatively few samples were taken during those periods of reduced efficiency, and thus most of the results represent the normal efficiency exclusive of this period. A study has been made, however, of the results of examinations of samples taken directly after washing, somewhat in detail. The following is a tabular statement of the average results obtained from each filter by months, including only the results obtained on those days when samples were taken within twenty minutes after washing, the results of other days being excluded:—

AVERAGE NUMBER OF BACTERIA IN EFFLUENT.

WARREN FILTER.

	Shown by Record Sheets.	Within 10 Minutes After Washing.	11 to 20 Minutes After Washing.	More than 20 Minutes After Washing.
February	115	...	118	114
March	316	50	515	301
April	79	417	207	75
May	(Special experiments, omitted.)			
June	197	493	272	170
July	300	...	546	207
August	174	356	601	223

JEWELL FILTER.

February	2,453	2,425	...	2,099
March	455	657	958	354
April	99	665	462	165
May	144	998	346	127
June	(Special experiments, omitted.)			
July	279	1,330	272	274
August	344	612	323	376

The time of inferior work very rarely exceeded twenty minutes. It will be seen from the tables that the results as shown by the record sheets are never very much higher, and are occasionally lower than the results of samples taken on corresponding days more than twenty minutes after washing; and thus while a decrease in bacterial efficiency was noted after washing, no material increase in the average bacterial efficiency of the mechanical filters would have been obtained if these results had been excluded. The results for the whole time would be affected much less than is indicated by the table, because the table includes only results of those days when samples were taken just after washing, while the much larger number of days when no such samples were taken would show no change whatever.

It has been suggested that these inferior effluents after washing should be wasted. Such a procedure would mean wasting probably on an average two per cent. of the water filtered, and a corresponding increase in the cost of filtering. Mr. Fuller[1] in his Louisville Report comes to the conclusion that with adequate washing and coagulation it is unnecessary to waste any effluent, and that inferior results after washing usually indicated incomplete washing. While our experiments certainly indicate a reduction in efficiency after washing so regular and persistent as to make it doubtful whether incomplete washing can be the cause of it, it may be questioned whether or not wasting the effluent would be necessary or desirable in actual operation. At any rate, the results as given in this report are not materially influenced by this factor.

Influence of Amount of Sulphate of Alumina on Bacterial Efficiency of Mechanical Filters.

The number of bacteria passing a mechanical filter is dependent principally upon the amount of sulphate of alumina used, and by using a larger quantity of sulphate of alumina than was actually used in the experiments the bacterial efficiency could be considerably increased. To investigate this point, the results obtained each day with each of the mechanical filters were arranged in the order of the sulphate of alumina quantities used, and averaged by classes. In this and the following tables a few abnormal results were omitted.[2] A summary of the results is as follows:—

[1] Fuller:—Water Purification at Louisville; Page 425.

[2] Warren,—Feb. 9, June 1, July 6. Jewell,—July 1, Feb. 9, 16, 17.

SUMMARY OF RESULTS WITH WARREN MECHANICAL FILTER.

ARRANGED ACCORDING TO SULPHATE OF ALUMINA QUANTITIES.

Number of Days Represented.	Turbidity.	Bacteria. Raw Water.	Bacteria. Effluent.	Per Cent. Remaining.	Per Cent. Removed.	Sulphate of Alumina Used, Grains Per Gallon.
7	0.05	4,773	1,713	35.89	64.11	0.00
2	0.08	2,785	850	30.52	69.48	0.12
4	0.10	5,109	726	14.21	85.79	0.26
2	0.20	8,713	214	2.45	97.55	0.36
8	0.06	3,224	112	3.47	96.53	0.44
19	0.06	3,488	123	3.53	96.47	0.55
11	0.06	5,673	154	2.71	97.29	0.64
10	0.10	6,100	112	1.84	98.16	0.74
8	0.09	8,647	148	1.71	98.29	0.85
5	0.16	5,645	142	2.52	97.48	0.93
13	0.12	10,397	200	1.92	98.08	1.07
10	0.08	12,778	121	0.95	99.05	1.13
13	0.14	13,397	164	1.22	98.78	1.25
19	0.13	10,462	160	1.53	98.47	1.34
10	0.12	12,851	107	0.83	99.17	1.46
4	0.27	16,015	77	0.48	99.52	1.57
7	0.53	12,262	191	1.18	98.82	1.64
4	0.58	26,950	347	1.29	98.71	1.74
5	0.29	14,570	86	0.59	99.41	1.84
3	0.23	13,833	153	1.11	98.89	1.92
19	0.40	18,222	92	0.50	99.50	2.48
5	0.45	29,300	1,119	3.82	96.18	3.37
5	1.06	33,030	535	1.62	98.38	8.06

SUMMARY OF RESULTS WITH JEWELL MECHANICAL FILTER.

ARRANGED ACCORDING TO SULPHATE OF ALUMINA QUANTITIES.

Number of Days Represented.	Turbidity.	Bacteria. Raw Water.	Bacteria. Effluent.	Per Cent. Remaining.	Per Cent. Removed.	Sulphate of Alumina Used, Grains Per Gallon.
6	0.03	14,037	6,217	44.29	55.71	0.00
5	0.07	4,267	680	15.93	84.07	0.24
14	0.06	2,613	170	6.50	93.50	0.35
10	0.06	2,446	113	4.62	95.38	0.44
9	0.11	7,303	234	3.20	96.80	0.55
20	0.09	6,979	220	3.15	96.85	0.65
9	0.08	5,191	130	2.50	97.50	0.75
16	0.12	8,504	242	2.84	97.16	0.83
22	0.16	8,506	99	1.16	98.84	0.96
12	0.11	11,998	246	2.05	97.95	1.05
14	0.18	18,982	423	2.23	97.77	1.16
5	0.14	13,981	224	1.60	98.40	1.23
9	0.27	19,806	325	1.64	98.36	1.34
14	0.27	16,549	324	1.96	98.04	1.45
9	0.29	12,194	96	0.79	99.21	1.54
6	0.25	13,483	51	0.38	99.62	1.65
7	0.53	24,243	220	0.91	99.09	1.72
3	0.90	20,953	602	2.88	97.12	1.90
5	0.43	25,958	307	1.19	98.81	2.19
4	0.84	21,017	228	1.09	98.91	3.71

These results are shown graphically on the accompanying diagram.*

* See Plate No. 7, opposite Page 52.

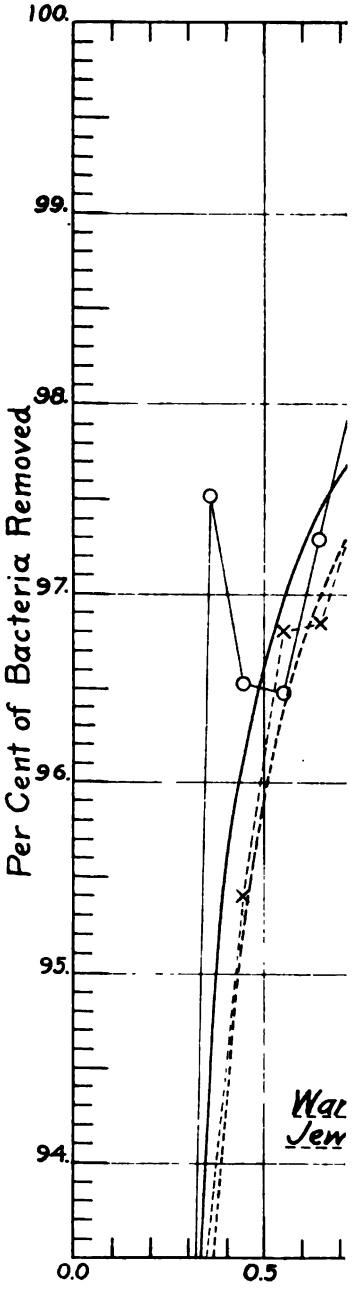
Influence of Degree of Turbidity upon Bacterial Efficiency of Mechanical Filters.

It will be noticed by referring to the tables that as the sulphate of alumina quantities increased the turbidities increased and the numbers of bacteria increased, as well as the bacterial efficiencies. That is to say, with the less turbid waters, small sulphate of alumina quantities have been used, the numbers of bacteria in the raw water have been low, and the bacterial efficiencies have also been low. With turbid waters much larger quantities of sulphate of alumina have been used, the raw water has contained more bacteria, and the bacterial efficiencies have been much higher. It may be then, that the increased efficiencies with increased quantities of sulphate of alumina are not due alone to the increased sulphate of alumina, but in part also to other conditions. Thus it may be easier to remove a large percentage of bacteria from a water containing many than from a water containing only a few.

To investigate this matter and eliminate the influence of turbidity and numbers of bacteria in the raw water, the results were first classified with reference to turbidity. The results with waters having turbidities of 0.10 or less, and called for convenience turbid waters, are arranged by alum quantities as before. Afterwards the results obtained with turbidities from 0.11 to 0.50, and called for convenience muddy waters, are grouped; and finally the results with waters having turbidities of 0.51 and over, and called for convenience thick waters. The results thus arranged are as follows:—

SUMMARY OF RESULTS WITH WARREN MECHANICAL FILTER.
ARRANGED ACCORDING TO TURBIDITIES AND SULPHATE OF ALUMINA QUANTITIES.

Number of Days Represented.	Turbidity.	Bacteria. Raw Water.	Bacteria. Effluent.	Per Cent. Remaining.	Per Cent. Removed.	Sulphate of Alumina Used, Grains Per Gallon.
7	0.05	4,773	1,713	35.89	64.11	0.00
2	0.07	2,785	850	30.52	69.48	0.12
12	0.06	3,209	224	7.00	93.00	0.42
31	0.06	4,238	119	2.81	97.19	0.60
9	0.06	7,953	130	1.64	98.36	0.84
16	0.04	11,265	137	1.22	98.78	1.11
29	0.06	11,500	158	1.37	98.63	1.58
5	0.17	8,783	416	4.73	95.27	0.36
10	0.16	6,535	165	2.54	97.46	0.85
13	0.19	13,253	186	1.40	98.60	1.13
15	0.22	10,944	93	0.85	99.15	1.36
13	0.29	14,089	112	0.80	99.20	1.73
10	0.35	18,088	102	0.57	99.43	2.38
5	0.29	25,580	540	2.11	97.89	4.30
6	0.87	25,433	369	1.45	98.55	1.74
6	0.73	26,566	79	0.30	99.70	2.64
4	1.35	42,037	1,388	3.30	96.70	8.16


100.
99.
98.
97.
96.
95.
94.
Per Cent of Bacteria Removed
0.0
0.5
Wat
Jew

SUMMARY OF RESULTS WITH JEWELL MECHANICAL FILTER.
ARRANGED ACCORDING TO TURBIDITIES AND SULPHATE OF ALUMINA QUANTITIES.

Number of Days Represented.	Turbidity.	BACTERIA. Raw Water.	BACTERIA. Effluent.	Per Cent. Remaining.	Per Cent. Removed.	Sulphate of Alumina Used, Grains Per Gallon.
6	0.03	14,037	6,217	44.29	55.71	0.00
3	0.07	5,170	991	19.15	80.85	0.21
25	0.05	2,403	143	5.95	94.05	0.38
20	0.06	6,531	185	2.84	97.16	0.64
27	0.06	5,811	122	2.10	97.90	0.88
14	0.06	14,978	412	2.75	97.25	1.11
10	0.06	15,787	390	2.47	97.53	1.37
10	0.05	10,847	47	0.43	99.57	2.17
14	0.16	7,525	256	3.40	96.60	0.60
17	0.24	11,310	208	1.84	98.16	0.91
15	0.24	15,441	262	1.70	98.30	1.13
10	0.28	17,842	232	1.30	98.70	1.43
8	0.29	9,556	59	0.62	99.38	1.59
4	0.29	20,212	135	0.67	99.33	2.00
5	0.66	23,680	336	1.42	98.58	1.42
7	0.96	30,200	475	1.57	98.43	1.74
4	1.25	37,587	496	1.32	98.68	2.81

The following table shows the bacterial efficiencies with turbid, muddy and thick waters, with substantially equal quantities of sulphate of alumina:—

WARREN FILTER.

GRAINS OF SULPHATE OF ALUMINA. Turbid.	Muddy.	Thick.	CORRESPONDING BACTERIAL EFFICIENCIES. Turbid.	Muddy.	Thick.
0.42	0.36	....	93.00	95.27	.....
0.84	0.85	....	98.36	97.46	.....
1.11	1.13	....	98.78	98.60	.....
1.58	1.73	1.74	98.63	99.20	98.55
....	2.38	2.64	.....	99.43	99.70
....	4.30	8.16	.....	97.89	96.70

JEWELL FILTER.

0.64	0.60	....	97.16	96.60	.....
0.88	0.91	....	97.90	98.16	.....
1.11	1.13	....	97.25	98.30	.....
1.37	1.43	1.42	97.53	98.70	98.58
2.17	1.59	1.74	99.57	99.38	98.43
....	2.00	2.81	.....	99.33	98.68

It appears from this table that waters of various degrees of turbidity give substantially equal bacterial efficiencies with equal quantities of sulphate of alumina, the results varying as often in one direction as the other. Within certain limits it may thus be said that turbidity is without influence upon the bacterial efficiency obtained in mechanical filtration.

It must be borne in mind, however, that the quantities of sulphate of alumina, with very few exceptions, were sufficient to produce full coagula-

tion. Mr. Fuller has shown in his Louisville Report that considerable quantities of sulphate of alumina may be added to turbid waters without producing appreciable coagulation, and therefore if a quantity of sulphate of alumina sufficient to produce a certain bacterial efficiency in a clear water should be added to a water so turbid that it was unable to coagulate it, scarcely any effect would be produced. The above statement therefore only applies in those cases where sufficient sulphate of alumina is used to adequately coagulate the water.

As the numbers of bacteria often vary with the turbidity, the variation in the numbers of bacteria in the different classes is much less than in the first tables; but to further investigate the question of whether the numbers of bacteria in the raw water have an important influence upon the bacterial efficiencies, each of the two largest classes in the foregoing tables were divided into two parts, according to the bacterial numbers in the raw water, namely, the results from the Jewell Filter with turbid waters and with sulphate of alumina quantities ranging from 0.75 to 1.00 grain per gallon, and the results from the Warren Filter with turbid waters and with sulphate of alumina quantities of 1.25 grains per gallon and upward. The results are as follows:—

JEWELL FILTER.

Number of Days Represented.	Turbidity.	Bacteria. Raw Water.	Bacteria. Effluent.	Per Cent. Remaining.	Per Cent. Removed.	Sulphate of Alumina Used, Grains Per Gallon.
14	0.05	3,938	81	2.06	97.94	0.88
13	0.07	7,827	167	2.13	97.87	0.87

WARREN FILTER.

15	0.06	3,545	59	1.66	98.34	1.67
14	0.06	20,022	265	1.32	98.68	1.48

It will be observed that the bacterial efficiencies are substantially the same, with the lower and with the higher numbers of bacteria in the raw water. That is to say, other things being equal, as the number of bacteria increase in the raw water the number of bacteria in the effluent increase in the same ratio. A further analysis of other groups of results would perhaps show variations in one direction or the other, but on the whole it is believed that the comparison is a fair one, and that there is no well marked tendency for bacterial efficiencies of mechanical filters to increase or decrease with increasing numbers of bacteria.

Average Results Obtained with Various Quantities of Sulphate of Alumina.

As it appears that neither the turbidity nor the number of bacteria in the raw water have a material influence upon the percentage of bacterial efficiency obtained, we can take the results given above, which include all the results obtained (except a very few abnormal ones) for computing

the various efficiencies obtained with various quantities of sulphate of alumina. These results are graphically shown on the accompanying diagram, on which lines have been drawn indicating the normal efficiencies from various quantities of sulphate of alumina as deduced from our experiments.[1]

In computing the amount of sulphate of alumina which it would be necessary to use in operating a plant at Pittsburgh to give these efficiencies, the quantities of sulphate of alumina shown by the diagram can be taken as those which it would be necessary to use during those days in the year when the raw water was clear, or sufficiently clear, so that the amounts of sulphate of alumina mentioned would suffice to properly coagulate it.

Amount of Sulphate of Alumina Required to Clarify Turbid Waters.

With the most turbid waters certain quantities of sulphate of alumina are required for coagulation, irrespective of bacterial efficiency. In order to determine these amounts of sulphate of alumina, all the results with raw water turbidities of 0.10 and over have been arranged by themselves, and have been plotted on the accompanying diagram.[2]

It should be remembered that many of the quantities of sulphate of alumina shown on this diagram were used to secure high bacterial efficiencies and without reference to the turbidity, and therefore the minimum rather than the average amounts should be considered. On the other hand, the quantities of sulphate of alumina were occasionally insufficient to produce entirely clear effluents. Bearing these facts in mind, lines have been drawn representing the amounts of sulphate of alumina which it may be considered necessary to use with the Warren and Jewell Filters with the turbidities given to produce, in general, clear effluents. These lines start at 0.30 of a grain of sulphate of alumina for perfectly clear waters, and reach 2.00 grains with the Jewell and 2.75 grains with the Warren for turbidities of 1.00. No doubt the amount of sulphate of alumina required to clarify turbid waters depends somewhat upon the character of the material causing the turbidity; but the lines as drawn will be sufficiently accurate for the purposes of present computations.

Amount of Sulphate of Alumina Which Must Be Used.

If now we take the various efficiencies obtained with the various quantities of sulphate of alumina from the first plotting, and assume that these quantities of sulphate of alumina will be sufficient to clarify all waters up to the turbidities corresponding to these quantities, as shown by the second diagram, and then for the remaining days of the year

[1] See Plate No. 7, opposite Page 52.
[2] " " " 8, " " 56.

assume such larger quantities as will be sufficient to remove the sediment, as shown by the second diagram, we have the following results:—

WARREN FILTER.

Required Bacterial Efficiency.	Sulphate of Alumina Required for this Bacterial Efficiency with Least Turbid Waters.	This Quantity of Sulphate of Alumina is Sufficient for the Treatment of Waters With Turbidities up to	Extra Sulphate of Alumina Quantity for Higher Turbidities Reckoned on all the Water Treated for One Year.	Average Quantity of Sulphate of Alumina Required, Grains Per Gallon.
95.00	0.37	0.03	0.33	0.70
96.00	0.44	0.06	0.28	0.72
97.00	0.56	0.11	0.22	0.78
98.00	0.84	0.22	0.14	0.98
98.50	1.12	0.34	0.10	1.22
99.00	1.60	0.53	0.06	1.66
		JEWELL FILTER.		
95.00	0.42	0.07	0.18	0.60
96.00	0.49	0.12	0.15	0.64
97.00	0.65	0.21	0.10	0.75
98.00	0.96	0.39	0.06	1.02
98.50	1.48	0.70	0.02	1.50

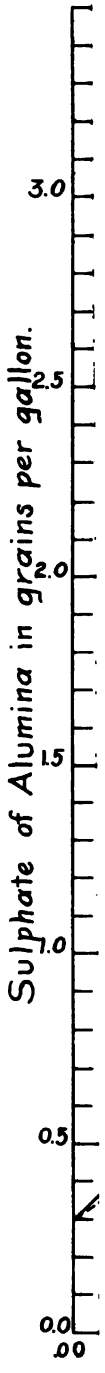
In the following table are shown the average quantities of sulphate of alumina which it will be necessary to use with the Warren and Jewell Filters to produce at all times ordinarily clear effluents, and to get average bacterial efficiencies, as shown in the first column. A third column has been added giving results between the Warren and Jewell, which results will be used for further computations in regard to the cost of operation of mechanical filters.

QUANTITIES OF SULPHATE OF ALUMINA REQUIRED TO PRODUCE CLEAR EFFLUENTS, AND THE BACTERIAL EFFICIENCIES MENTIONED.

Bacterial Efficiency.	Required with Warren Filter.	Required with Jewell Filter.	Used in Computation of Cost of Operation.
95.00	0.70	0.60	0.65
96.00	0.72	0.64	0.68
97.00	0.78	0.75	0.76
98.00	0.98	1.02	1.00
98.50	1.22	1.50	1.35
99.00	1.66	....	(1.70)

Action of Sulphate of Alumina and the Quantity of Sulphate of Alumina Which Can Be Safely Used.

All calculations thus far have been based upon the assumption that it is possible to use any quantity of sulphate of alumina which may be desired. As a matter of fact this is not the case, but the amount which can be used is dependent upon the amount of lime in the raw water. When sulphate of alumina is added to water it is decomposed, with the formation of alumina, which forms a flocculent precipitate, upon which its purifying action depends, and sulphuric acid which combines with the


Sulphate of Alumina in grains per gallon.
3.0
2.5
2.0
1.5
1.0
0.5
0.0
.00

calcium carbonate or lime present in the raw water. There should always be an excess of lime in the water. If, however, for any reason there is not, there is nothing to combine with the sulphuric acid, and the decomposition of the sulphate of alumina is not complete, and a portion of it goes undecomposed into the effluent. The effluent then has an acid reaction and is unfit for domestic water supply. When distributed through iron pipes it attacks the iron, rusting the pipes, and giving rise to all the disagreeable consequences of an iron-containing water.

The amount of lime in the water at any time available to combine with the sulphuric acid can be determined by a very simple chemical operation, and has been so determined at frequent intervals during the course of our experiments. The amount of sulphate of alumina corresponding to a given quantity of lime can be readily and accurately calculated, but it is not regarded safe to use as much sulphate of alumina as corresponds to the lime. The quantity of sulphate of alumina used is not susceptible to exact control, but fluctuates somewhat; and if the exact theoretical quantity should be employed during twenty-four hours, there would surely be an excess during some portion of that time, from which bad results would be experienced. It is therefore considered only prudent to use three-fourths as much sulphate of alumina as corresponds to the lime in the water.

The following table shows the average alkalinity or uncombined lime of the Allegheny River, and the amount of sulphate of alumina in grains per gallon which could be safely used with it. The sulphate of alumina is computed as having seventeen per cent. soluble alumina, that being the average strength used in our experiments.

Month. 1897.	Alkalinity Expressed as Calcium Carbonate. Parts Per 100,000.	Safe Amount of Sulphate of Alumina, Grains Per Gallon.
August	4.05	3.79
September	4.63	4.34
October	5.09	4.77
November	3.51	3.29
December	1.72	1.61
1898.		
January	1.48	1.39
February	1.73	1.62
March	1.75	1.64
April	1.83	1.72
May	2.12	1.99
June	3.10	2.90
July	3.41	3.20
August	3.15	2.95
Averages for Year, ending July 31, 1898	2.87	2.70

The alkalinity, and consequently the amount of sulphate of alumina which can be used, is, in a general way, inversely proportional to the amount of water flowing in the river. When the river is low in summer, the water carries a great deal of lime; while in winter, and especially in the spring freshets, it is made up largely of melted snow and rain water and carries but little lime. The lowest monthly average is for January, corresponding to 1.4 of a grain of sulphate of alumina to the gallon. For short intervals during floods, alkalinities considerably lower than the monthly averages were obtained during January, February, March, and April, the amounts being so low at times as to be only capable of decomposing one grain of sulphate of alumina to the gallon.

Mr. Fuller in the report of his experiments at Louisville has called attention to the fact that with very large amounts of suspended matter more sulphate of alumina can be used then corresponds to the alkalinity of the water. The explanation of this is apparently that some of the sulphate of alumina is absorbed by the clayey matter in suspension, and carried out as sulphate of alumina without being decomposed, and without taking up any of the lime in the raw water. It may be questioned whether the sulphate of alumina which has been absorbed in this way plays any part whatever in the purification. It allows the use of more sulphate of alumina than would otherwise be possible, however, and must thus be taken into consideration. Mr. Fuller* states as the results of his experiments that the percentages which the actual reductions in alkalinity by sulphate of alumina were of the theoretical percentages with the Ohio River water containing different amounts of suspended matter were as follows:—

Suspended Matter in Parts Per Million.	Percentages which the Actual were of the Theoretical.
200	85
400	80
800	75
1,200	65

The suspended matters in this table represent approximately the range during the freshet flows of the Allegheny River at Pittsburgh, and it may therefore be assumed that at these times the reductions in alkalinity will be about as given in the table; or putting it in another way, the amount of sulphate of alumina used may be increased from twenty to fifty per cent. above the amounts corresponding to three-fourths of the alkalinity. Making this allowance, it appears that at times the amount of sulphate of alumina which can safely be used with the Allegheny River water is not more than 1.2 to 1.5 grains per gallon. These times of minimum alkalinity are also, in general, times of maximum turbidity,

* Water Purification at Louisville, Page 54.

and the quantity of sulphate of alumina necessary for clarification is occasionally greater than the amount which can be safely taken by the water.

During the course of our experiments, and before this condition was fully realized, the amount of sulphate of alumina was, on several occasions, increased beyond the amount which could properly be received by the water, in the endeavor to maintain clear effluents, and acid and alum containing the effluents were the result. The effluents also were not clear at these times, and on a number of occasions turbid effluents were obtained from the mechanical filters with the best conditions which could be obtained, and in fact the conditions were such that clear effluents could not have been obtained by the use of any amount of sulphate of alumina, large or small. These times were not of frequent occurrence nor of long duration, and would probably not prevent securing a satisfactory effluent for municipal supply, as the rate of filtration could be reduced, as with sand filters, at these periods; but owing to the absence of the large sedimentation basins and the large quantities of water upon the sand filters, the reduction in rate which would be possible at these times would be relatively less with mechanical than with sand filters.

Another alternative would be to add lime to the water before adding the sulphate of alumina, making up the deficiency in alkalinity. In this way a much larger quantity of sulphate of alumina could be used without having it pass undecomposed into the effluent; but, on the other hand, the hardness of the water would be increased, and the process also made more complex and difficult of regulation. Soda ash could be used instead of lime, at a considerable increase in expense and without increasing the hardness. The use of lime and soda ash in any event should only be regarded as emergency measures during floods. The regular use of either of these substances would be attended with such disadvantages as to render it out of the question.

It will be seen that (throwing out of consideration the use of lime and soda ash) during six months of the year the water of the Allegheny River contains so little lime as only to make possible the use of from 1.2 to 2.0 grains of sulphate of alumina to the gallon. The use of larger quantities of sulphate of alumina, with corresponding bacterial efficiencies, is therefore impossible for the conditions at Pittsburgh. In fact there would be several months when enough sulphate of alumina could not be used to reach 1.70 grains to the gallon with a bacterial efficiency of 99 per cent. It may thus be said that, as far as our experiments have developed the case, the maximum average bacterial efficiency which can be obtained at Pittsburgh by mechanical filtration is rather less than 99 per cent. with the most efficient quantity of sulphate of alumina applied to the water, regardless of the cost.

COMPARISON OF THE QUALITIES OF EFFLUENTS OBTAINED BY SAND AND MECHANICAL FILTRATION.

Bacterial Efficiency.

The average bacterial efficiencies of filters on the respective systems, as developed by our tests, were an average of 99 per cent. for the sand filters, and from 97 to 98 per cent. for the mechanical filters. With the sand filters the efficiencies for the summer months, and particularly those months when the numbers of bacteria in the raw water were highest, were very much above this average, reaching during October, 1897, the remarkable efficiency of 99.96 per cent.

It is noticed throughout that the numbers of bacteria in the effluents from the sand filters vary less with changes in the numbers of bacteria in the raw water than do those in the effluents from mechanical filters. With the lowest numbers of bacteria in the river water a certain number are found in the effluents from the sand filters, and with the highest numbers the numbers in the effluents are often little or no greater. This circumstance, which has been observed with sand filters in many places, has led to the theory that these bacteria, within certain limits, result from growths in the underdrains and in the lower parts of the filters, and do not represent bacteria which have come through the sand. To a certain extent this deduction is correct, and it is a well established fact that the numbers of bacteria found in the effluents from sand filters represent more than the numbers which really pass the filters.

With mechanical filters, on the other hand, the action is so rapid, and the filter is stirred to the bottom so frequently, that there is no chance for growths of this kind, and the numbers of bacteria found in the effluents do actually represent the numbers of bacteria passing the filters. The importance of this difference lies in the fact that the bacteria which are capable of growing in the underdrains and lower parts of the sand filters are in no case injurious to health, and as far as the bacteria in the effluents are of this character, they are unobjectionable; and as this number is added to that of the bacteria which have actually passed through the filters, and are, or may be, objectionable, the apparent efficiency of the filter is reduced below the true efficiency.

The greatest numbers of bacteria in the effluents from sand filters occur during the winter, and at this time the numbers must be taken as representing, for the most part, bacteria which actually pass through, the conditions for growths in the underdrains being less favorable at this season of the year. During the winter months the bacterial efficiency fell to about 97 per cent. for a time. This reduction in efficiency would be avoided by the use of covered instead of open filters.

With mechanical filters, the percentage of bacteria passing was considerably greater than with the sand filters. By using a larger quantity

of sulphate of alumina than was used during our experiments, it would be possible to obtain higher bacterial efficiencies, possibly as high as 99 per cent. This would be equivalent to the average yearly work of open sand filters, but not equivalent to the work which could be secured from sand filters during summer, or from covered filters all the year round.

Some special experiments demonstrated the sensitiveness of mechanical filters to the constant application of sulphate of alumina. When, for the purpose of experiment, the addition of sulphate of alumina to the water was interrupted, the bacteria in the effluent increased in about the length of time which was required for the water to pass through the apparatus, and in a short additional time the bacteria in effluent became a considerable percentage of those in the raw water. The importance of this will be at once appreciated, as in a mechanical filter plant if the sulphate of alumina applied should be interrupted at any time temporarily the efficiency of the filter disappears.

On the whole, the bacterial efficiency of the sand filters has been very much better than that of the mechanical filters. By using more sulphate of alumina, better bacterial efficiency could be secured with mechanical filters than the average results of our experiments with them; but the efficiency which can be secured in this way would not be as great in any case as that of sand filters protected from winter weather.

Clearness of Effluent.

As has been shown, there are times when neither sand filters nor mechanical filters are capable of producing perfectly clear effluents from the Allegheny River water. The times when sand filters cannot produce clear effluents are more frequent and last longer than the times when mechanical filters cannot produce clear effluents, and the mechanical filters in this respect are distinctly superior to the sand filters. It is believed, however, that a plant on either system, properly constructed and operated, would yield effluents entirely unobjectionable in this respect. With sand filters, the turbidity of effluents can always be kept within 0.02 by reducing somewhat the rate of filtration for the short times when the turbidity in the river is exceptionally high, and this turbidity is such as not to be particularly noticeable in an ordinary drinking glass. These periods of maximum turbidity of the river water are quite short, and by drawing somewhat upon the stored water in the reservoirs at these times, the difficulties of filtration will be materially less than they were in our experiments, in which the attempt was made to maintain the full rates of filtration at all times, regardless of the character of the raw water.

Color.

The water of the Allegheny River after filtration is almost entirely colorless. It has, however, occasionally a yellow color, due to peaty matter. The origin of this peaty matter has not been traced in detail, but it appears probable that one or more of the upper tributaries of the river are of a peaty character, and that when these branches are in flood, the water from them is sufficient to color slightly the water of the river at Brilliant.

At these times a considerable portion of the color passes through the sand filters, but is removed by the action of the sulphate of alumina in the mechanical filters. The highest color observed in the effluents from sand filters was about 0.30. Colors of 0.15 are exceptional, and the average for the year ending August 31, 1898, was 0.07 for both sand filters. When it is considered that many Eastern cities have water supplies, generally considered satisfactory, having colors upon the same scale ranging from 0.50 to 1.00, it will be seen that these colors are quite slight, and will hardly be open to serious objection.

Hardness.

Both sand and mechanical filters have increased somewhat the hardness of the water during our experiments, but in different ways. The sand filters have increased the temporary, while the mechanical filters have increased the permanent hardness. In the mechanical filters the increase in hardness is due to the change of lime from carbonate to sulphate, or from temporary to permanent hardness, the total hardness remaining unchanged. With the sand filters the permanent hardness has remained unchanged, while the temporary hardness has been increased by the solution of a certain amount of carbonate of lime contained in the sand. During the period covered by our experiments more than sixty per cent. of the lime originally present in the sand has been dissolved out, as is shown in the following table:—

	Filter No. 1.	Filter No. 2.
Approximate weight of sand in filter at commencement of experiments, pounds	115,600.00	114,000.00
Quantity of lime in sand, per cent.....	1.32	1.35
Weight of lime in original sand, pounds..	1,525.00	1,539.00
Average amount of lime in sand, Sept., 1898, per cent.....	0.53	0.43
Lime removed, per cent. of original lime..	60.00	68.00
Lime removed in pounds	913.00	1,048.00
Approximate quantity of water filtered, gallons 7,547,530.00		7,843,830.00

	Filter No. 1.	Filter No. 2.
Average increase in hardness, parts per 100,000	1.09	1.28
Weight of lime in pounds, corresponding to this increase in quantity	685.00	836.00

It is observed from the above that the lime will be exhausted before another year, and with its exhaustion the increase in hardness will be stopped. It was found after the experimental filters were filled that the sand used in them contained more lime than sands from certain places in the river. It would therefore probably be possible to select sand containing less lime than that which was actually used in the experimental filters.

Boiler Tests.

In order to put the filtered water to practical tests three 25 horse-power boilers were secured, as described in detail in the report of the Resident Engineer, and operated for some months, one being supplied with raw water, one with water from the mechanical filters, and one with water from the sand filters. It appears from the results, given in detail in the above mentioned report, that the boiler receiving the raw water produced much the largest quantity of scale, but that this scale was soft and readily removed. Both of the filtered waters produced a harder scale, although less in quantity. The water filtered through the mechanical filters produced somewhat more scale than the water from the sand filters and it also attacked the iron in places. The boilers were not operated during the periods of greatest muddiness, and consequently the boiler receiving the raw water probably compared more favorably with the boilers receiving the filtered waters than would have been the case at other seasons of the year.

The average results of turbidity, color, bacteria, and hardness of the river water, mechanical filters, and Sand Filter No. 1, for the seven months, ending August, 1898, but excluding results obtained during special experiments with mechanical filters, are as follows:—

	River Water.	Mechanical Filters.	Sand Filter No. 1.
Turbidity	0.200	0.003	0.010
Color	0.26	0.03	0.07
Bacteria	11,337	247	106
Total Hardness	3.31	2.97	4.31
Temporary Hardness	2.56	1.66	3.53
Permanent Hardness, or Encrusting Constituents	0.75	1.31	0.78

It thus appears that the sand filter produced effluents with rather more than twice as much color and turbidity as the mechanical filters, while the mechanical filters produced effluents with more than twice as many bacteria as the sand filter. Temporary hardness was increased by the sand filter, but as shown above, there is reason for the belief that this increase will not be continued. With the mechanical filters the permanent hardness, or encrusting constituents, were increased 75 per cent., while no increase occurred with the sand filter.

COST OF CONSTRUCTION OF FILTERS.

The question of relative costs of filters upon the different systems is an important matter to be taken into consideration in deciding between them, and estimates have been made of the cost of constructing and operating sand and mechanical filters. The present consumption of water in Pittsburgh is fifty million gallons daily. On some days the consumption is much greater than the average for the year. It is necessary to provide filters for the maximum rather than for the average consumption. In general, with a reservoir system like that at Pittsburgh, it is safe to provide filter units having a nominal capacity fifty per cent. above the annual average consumption, or for Pittsburgh seventy-five million gallons daily. The twenty-five millions capacity between the aggregate nominal capacity of the filters and the average annual consumption is sufficient to allow the highest daily consumption to be supplied with ease, and to serve as a reserve for cleaning, renewals, and repairs.

In the estimates in each case sufficient land has been included to allow the plant to be doubled, and estimates for some of the structures not capable of being readily enlarged are sufficient for a large increased consumption. The remaining items are of such nature that their cost would be nearly proportional to the quantity of water to be provided. For our present purpose, then, it may be taken as sufficiently exact to assume that the cost of constructing filter plants will be directly proportional to the capacities of the same, and the estimates given can be used for larger or smaller plants, by the application of appropriate factors.

The estimates are as follows:—

Estimates of Cost of Construction of Filter Plants,

	Sand Filters with Sedimentation Basins.	Sand Filters with Storage Reservoir.	Mechanical Filters, North of River.	Mechanical Filters, South of River.
Intake, Pumping Machinery, and Pump House	$ 315,000	$ 455,000	$ 315,000	$ .....
Sedimentation Basin	200,000	.....	.....	.....
Raw Water Reservoir	.....	442,000	.....	.....
Filters	751,000	751,000	600,000	660,000
Filter House, Boilers, Pumps, Electric Lights, etc.	.....	.....	258,800	400,000
Pure Water Reservoir	133,000	133,000	133,000	.....
Force Main and Conduits	78,600	210,300	57,500	467,200
Tunnel Under River	60,000	60,000	60,000	.....
Engineering and Contingencies, 10 per cent.	153,760	205,130	142,430	152,720
Total Cost of Construction	$1,691,360	$2,256,430	$1,566,730	$1,679,920
Land, with reserve area to double plant	420,000	312,500	75,000	50,000
Total Estimated Cost	$2,111,360	$2,568,930	$1,641,730	$1,729,920

The estimates for sand filters are for open filters with an effective filtering area of twenty-five acres. The additional cost of covering with a masonry vaulting would be $375,000.

The estimates for mechanical filters apply equally to the Warren and Jewell Systems. While our tests were in progress the New York Filter Manufacturing Company acquired the patents covering both systems, and the prices are now uniform. It is probable that should mechanical filters be adopted for Pittsburgh, it would be desirable to use a type of filter differing somewhat from either the Warren or the Jewell Filters, as used in our experimental tests. It is not believed, however, that any required changes in design will affect materially the cost of the filters.

The pumping station in connection with the sand filters and storage reservoir will operate against a greater head than the other pumping stations, and its cost is therefore greater. With mechanical filters on the south side of the river two independent plants are required, each supplying a separate part of the city; and because of uncertainties in the exact division of consumption in the two parts, the aggregate capacity of the filters is taken as ten per cent. greater than that of a plant at one point on the north side of the river. The cost of buildings, boilers, pumps, electric lights, etc., is also materially greater, because two separate plants are required instead of one, and because the sites are much less favorable to construction than that upon the north side of the river.

No estimates have been made of the cost of constructing mechanical filters independent of the New York Filter Manufacturing Company, as this company controls certain patents. After the expiration of these patents it will be possible to construct mechanical filters independent of this company, and perhaps at a smaller cost than the prices now asked.

Plans* are transmitted herewith, showing the locations of the various structures and the land areas included in the various estimates and their cost in detail; but as the exact location of filters can be varied if necessary, I would suggest that it should not be determined upon until after the necessary land has been acquired. As I am not familiar with the value of real estate in Pittsburgh, I shall rely upon you to correct my estimate for land should that be necessary.

COST OF MAINTENANCE.

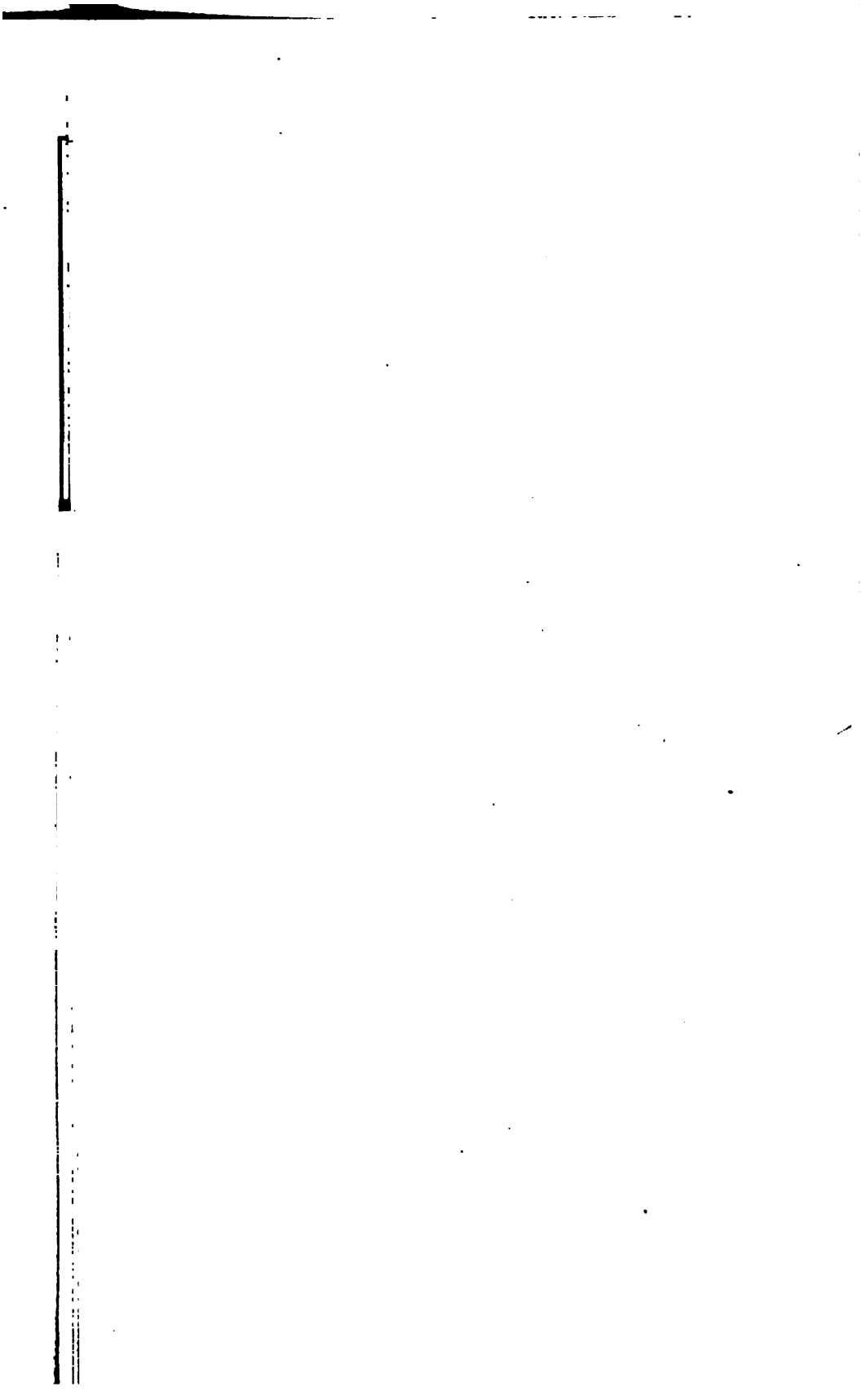
Estimates have been made of the cost of maintenance of the filters upon the various systems as follows:—

	Sand Filters with Sedimentation Basins.	Sand Filters with Storage Reservoir.	Mechanical Filters, North of River.	Mechanical Filters, South of River.
Interest	$ 68,619	$ 83,490	$ 53,356	$ 56,222
Depreciation	28,885	39,277	43,573	40,461
Pumping Costs	32,579	40,100	33,533	18,793
Operation of Filters, exclusive of Coagulant	62,101	45,625	32,120	36,500
Coagulant, 1 grain of Sulphate of Alumina	.....	.....	34,225	.....
Total Cost per Annum	$192,184	$208,492	$196,807	$186,201
Cost per Million Gallons	10.53	11.42	10.78	10.20

Interest has been taken on the entire estimated costs of the plants at 3½ per cent. Depreciation has been reckoned as follows:—No depreciation has been allowed upon land. On the intake, pumps, boilers, and mechanical filters an annual charge of 3.722 per cent. is made, which sum, placed at three per cent. compound interest, is sufficient to produce a fund equal to the original cost in twenty years. On the buildings and all masonry and other more permanent structures an annual charge of 1.326 per cent. is made, which charge is sufficient, computed as above, to produce a fund equal to the original cost in forty years. In computing the depreciation the proportionate charges for engineering and contingencies have been allowed.

Some of the masonry structures included in the forty-year class would be entirely permanent in character, and there would be no depreciation upon them. It is thought best, however, to make the charges

* See Plate No. 9, opposite Page 66.



upon all structures, on the ground that with increasing population upon the water-shed, it is not certain that the Allegheny River water, even with filtration, will be a suitable source of supply for Pittsburgh at the point now selected for a longer period than forty years, and it is therefore advisable to provide for the payment of all indebtedness incurred on account of this plant within that period of time.

With the mechanical filters, pumps, and other machinery, on which depreciation is reckoned sufficient to replace them in twenty years, certain parts will undoubtedly be in good order and capable of service much longer than that period. Other parts of the machinery will require to be replaced at much earlier dates. On the whole, it is believed that a twenty-year life is a conservative estimate for the pumps and filters. In the case of mechanical filters there is a reason for limiting the estimated life of the plant not existing in the case of the pumps, namely, the probable change in the types of filters, and consequent antiquation of the plant.

In the past the change in the types of mechanical filters has been very rapid. At the present time no plant is in existence which has been used for five years which would be considered as reasonably satisfactory. The type of filter has, however, been much improved, and it would not be fair to assume that changes will take place as rapidly in the future as they have done in the past, and that the plant now constructed would be incapable of future economical use in five years. On the other hand, it is not safe to assume that the plant now installed will continue to be reasonably satisfactory for a very long period of years; and aside from the question of rusting, wearing, and breaking of parts, it is not believed that it is prudent to take the life of these filters at more than twenty years.

Pumping costs and operating expenses are reckoned on an average daily consumption of fifty million gallons per day. The pumping costs include in the first three estimates the costs of lifting water from the river to the filters, and in the fourth estimate includes the cost of pumping for the additional height and the cost of pumping the additional quantity of water required for washing filters. The operation of filters, exclusive if coagulant, includes additional cost of pumping wash water, labor. fuel, new sand, repairs, superintendence, and all costs connected therewith.

The cost of sulphate of alumina is taken at $25.00 per ton, or two dollars less than the current market price, as I am assured that with the quantity which would be required it would be possible to secure it at this price. The amount assumed, one grain per gallon, is somewhat less than was used in our experiments, and is as small an amount as it is believed that it will be possible to use to secure an effluent that would be reasonably satisfactory. Should a larger quantity of sulphate of

alumina be employed to bring the bacterial efficiency up nearer to that secured by sand filtration, the cost would be increased at the rate of $0.187 per million gallons for each tenth of a grain per gallon.

FINAL COMPARISONS, SAND AND MECHANICAL FILTERS.

The comparison between sand and mechanical filters stands briefly thus:—With an amount of sulphate of alumina which makes the costs of the two processes substantially equal, the mechanical filters yield effluents containing from two to three times as many bacteria as the sand filters, and are consequently two or three times as likely to transmit disease germs, while, on the other hand, the effluents are clearer and more nearly colorless. In the adaptability of the filtered water to mechanical purposes the differences between the two will not be very great, but such differences as there are will be in favor of sand filters. If the raw water were very much more muddy than it is and contained less sewage, the advantage would be on the side of the mechanical filters, or at least the use of coagulant would be necessary. If, on the other hand, the water were less muddy and contained more sewage and sewage bacteria, the advantage would be decidedly with sand filters. Considering the fact that mud is not likely to increase, while the amount of sewage entering the river is sure to increase, and at a rapid rate, I believe that sand filters will be more satisfactory to the city than mechanical filters.

NECESSITY OF A STORAGE RESERVOIR FOR RAW WATER.

Nearly all of the difficulties in treating the Allegheny River water come at flood periods. It is only at these times that sand filters refuse to give practically clear effluents, and it is at these times also that mechanical filters require more sulphate of alumina for coagulation than can be neutralized by the lime in the water, and consequently the water passes with inadequate purification. The periods of excessive turbidity at Pittsburgh are of short duration. The worst water rarely lasts over twenty-four hours, and in no case, over three or four days. Moderately turbid waters sometimes continue for a week or more, but not of such a degree as to give serious trouble in their purification.

The difficulties with very turbid waters would be entirely eliminated by the construction of a reservoir large enough to hold a ten days' supply of water, and estimates for such a reservoir have been made in connection with sand filtration. The reasons for constructing such a reservoir are almost equally urgent with mechanical filtration, and the cost of a mechanical filtration plant in place of the sand filters in connection with such a reservoir would not differ materially from that of the plant covered by the second estimate. With raw water as clear as that which this reservoir would assure at all times, the advantages

would all lie with sand filtration and it has therefore not been necessary to take up in further detail mechanical filtration in connection with this reservoir.

The reservoir site is a run on the north side of the river, conveniently situated with reference to the proposed location of other parts of the work. The natural drainage area tributary to this site is about five square miles, and the natural run-off from this area would flow into the reservoir, reducing slightly the amount to be pumped from the river. The population upon the water-shed is entirely rural, and is roughly estimated at sixty per square mile. The water secured from it would be fully equal in quality to that from the Allegheny River.

In rainy weather the inflow into the basin from its own water-shed would be the largest, and the water received in this way would be quite turbid. The reservoir is so large, however, that it is believed this turbid water would not reach the outlet until it had been so long detained in the reservoir as to have deposited most of its sediment, and the water could thus be drawn from the reservoir to the filters at all times nearly free from suspended matters. In the same way, if it should be necessary to pump somewhat muddy water from the river to the reservoir, a very thorough sedimentation would take place before the water passed from the reservoir to the filters.

The construction of this reservoir would add materially to the cost of filtration, and its chief advantage would consist in that it would be possible at all times to supply perfectly clear water. We have demonstrated, however, from our experimental plant, that with sedimentation not exceeding twenty-four hours, it is possible to secure effluents at all times with only slight turbidities; and it is a question whether the removal of the last trace of turbidity is worth the additional cost of nearly half a million dollars which this reservoir represents. It would seem for the present to be the wiser policy to construct filters with only a sedimentation basin capacity equal to the average daily consumption; and if at some future time it is found that the remaining turbidity in the effluents justifies the additional expense, the reservoir can be added, and the space occupied by the sedimentation basins can then be utilized for extending the filters to meet the increased consumption. Sedimentation basins have been built over into filters repeatedly in European filtration plants, and it is often possible to utilize them in this way to very good advantage.

OTHER METHODS OF FILTRATION CONSIDERED.

Several other methods of filtration have received our attention. One of these, namely, the Worms Tile System, was examined experimentally at some length. This system is covered by certain patents, and the

owners of these patents have informed us that the cost of tiles would be twenty dollars each. To supply the quantity of water required by our estimates at the rates of filtration found possible in the experimental trials, the cost of tiles alone would exceed $1,000,000. When this amount is added to the cost of setting up and connecting the tiles, and the cost of necessary appurtenances and land intake, pumping station, pure water reservoir, etc., it is apparent that the cost of the plant will not be less than two and one-half million dollars, and may reach three million dollars. There is reason to think that the operating expenses would be greater than the operating expenses of either sand or mechanical filters; and as the experiments did not give assurance that the requisite quantity of pure water could be secured under all conditions, this process has not been considered further.

Several other processes have been called to our attention which involve the use of more or less peculiarly constructed sand filters, at rates of filtration several times as great as are commonly used for sand filters. Without raising the question of the adaptability of these systems to other conditions, it is certain that no system of sand filtration without coagulant will effectively clarify the Allegheny River water at rates more than several times as great as those which were used during our experiments.

The use of asbestos applied to the surface of sand filters has also been suggested. This process is covered by a patent, and if used would hardly increase the yield or efficiency of sand filters. It might reduce the operating expenses, and if so could be adopted and used at any time upon sand filters as ordinarily built, no special construction being necessary with it.

The question of the use of other coagulants than sulphate of alumina has not been considered by us. The report of Mr. Fuller upon the experiments at Louisville treats this matter quite fully; and there is no reason to suppose that any other coagulant could be substituted to advantage for the sulphate of alumina used in our experiments, and which serves as a basis of our estimates.

The use of natural filtration by galleries built in the bed of the Allegheny River has been suggested to us, with various modifications. A number of water supplies are now being drawn from the river in this way in the neighborhood of Pittsburgh, and these supplies have been investigated, as described in detail in the report of the Resident Engineer. It may be said in regard to them that the water thus secured is always harder than that secured by ordinary sand filtration, owing to the fact that the water is much longer in the sand, and comes in contact with a larger body of it. The difficulty of securing an adequate supply of water also increases much more rapidly than the required water quan-

tity. A million gallons per day is secured with comparative ease, but with two or three million gallons, the difficulties are very much increased, and with very large supplies they become almost insurmountable. The reason for this is that the amount of water which can be drawn from any stretch of river is limited, and that a very small crib serves to take the quantity of water which can be drawn from a certain area of river bottom. When the crib is enlarged, or other cribs are built in the neighborhood, they interfere with each other, drawing from the same area, with the result that the supply is not increased in proportion to the size of the cribs; and in order to secure a very large supply, it is necessary to construct structures extending over such a large extent of river bottom as to make their expenses absolutely prohibitive.

The use of domestic filters in each house in the city, to filter drinking water only, has been suggested. If the whole supply should be so filtered, the expenditure would be many times greater than that of a municipal plant. With only the drinking water filtered, it is not clear that the ultimate cost would be less than with one large plant, and the city would still suffer from many of the disadvantages of the present supply.

AUXILIARY SUPPLY OF UNFILTERED WATER FOR MANUFACTURING PURPOSES.

It has been suggested that the excessive consumption of water in Pittsburgh is due to the enormous quantity of water required for manufacturing purposes, and that it would be possible to build an auxiliary system for supplying unfiltered river water to these establishments, thereby reducing very much the quantity of water to be filtered.

As a matter of fact, the manufacturing establishments do not use as much water as is commonly supposed, or at least they do not draw such quantities from the city mains. Nearly all of the establishments requiring water in large quantities, for purposes for which the river water in its raw state is suitable, have their own pumping plants, and are able to pump water for their own use much cheaper than it can be supplied from the present city works, or from works especially constructed for that purpose. The reason for this is that while the pumping of water in relatively small quantities in various places is more expensive than pumping a large quantity at a central point, there are several important advantages in the arrangement. Each manufacturer pumps only against the head which he requires, and thereby saves all the friction in pipes and additional head to which a central plant would require to pump, because it would have to meet the highest pressure required by any one and not the average pressure; and further, the entire cost of the distribution system is saved, and this forms a large part of the cost of a central plant.

The estimated cost of an auxiliary pumping station for unfiltered

water, with intake and distribution system along the river fronts in that part of the city now supplied by the city works, is $565,000. If the system should be extended to supply also the south side of the Monongahela River, the cost is estimated at $660,000. This system would have a maximum capacity of twenty-five million gallons per day, and would be suitable for the supply of an average daily consumption of one-half this amount, or one-fourth of the quantity of water now supplied from the Brilliant pumping station.

The size of filters to be constructed at Brilliant, in case this amount of water should be diverted from the regular to the auxiliary supply, could be reduced one-fourth. The saving in the cost of filters would be, in round numbers, $400,000, and the saving in the cost of operation, including preliminary pumping, but exclusive of interest and depreciation, would be about $20,000 per annum. The cost of operating the auxiliary system may be taken as equivalent to the cost of pumping an equivalent quantity at Brilliant.

The use of an auxiliary system under the conditions assumed above would thus result, in round numbers, in an increased outlay of $165,000, and a reduction in operating expenses of $20,000 per annum. It would also make necessary certain changes in the distribution system of the water works, the importance of which cannot now be accurately estimated. The total saving would be comparatively small.

The above computation is based upon the assumption that one-fourth of the supply could be diverted to the auxiliary system. Let us consider now what the facts are in this respect. The quantities of water supplied to manufacturing and business establishments, as measured by meters and as estimated by the water assessors for the last fiscal year, amounted to an average of 3,700,000 gallons per day. A part of this quantity was used for purposes for which the raw river water would not be suitable. It should be remembered in this connection that an auxiliary pumping system would be located further down the river than the Brilliant Station, and the waters from it would be polluted by sewage from one of the city sewers, and would be far more objectionable hygienically than the present supply. Further, it would carry at least four times as much sediment as the present supply, as the water would be pumped into the pipes direct, without the removal of any sediment, while at least three-fourths of the sediment is now removed in the Highland Park Reservoir.

Many establishments included in the above list use water for purposes for which raw water of this quality would be utterly unsuitable, and I estimate that at least one-half of the quantity could not be diverted. There remain 1,850,000 gallons per day which could apparently be diverted to an auxiliary supply. Even if we add to this a liberal allowance

for the slip of meters and double the amounts estimated by the water assessors, we have only three million gallons per day which could be diverted, or one-fourth of the amount contemplated in the above estimate. This quantity is so small that a station supplying it would cost more, both in construction and in operation, than the saving to be effected in the cost of filtration by its diversion. It appears then that unless there is a demand for water of this quality far in excess of anything which now appears, it will be utterly impracticable to effect a saving to the department by the introduction of an auxiliary water supply.

There is a further important objection to an auxiliary pumping station, namely, that the employees in shops where such water is used are sure to drink it at times. The sanitary objections to such supplies are shown in the report of Prof. Sedgwick.

AMOUNT OF WATER TO BE PROVIDED AND THE RESTRICTION OF WASTE.

The quantity of water used in Pittsburgh is increasing very rapidly, as is shown by the following table, showing the populations supplied by water, and the average daily quantity of water pumped each year:—

Year.	Estimated Population in Wards 1 to 28 Inc.	Average Daily Quantity of Water Pumped.	Gallons Per Inhabitant.
1883	129,000	20,300,000	157
1884	135,000	22,700,000	168
1885	141,000	23,700,000	168
1886	147,000	25,800,000	176
1887	153,000	29,100,000	190
1888	159,000	29,500,000	186
1889	165,000	33,900,000	205
1890	171,000	36,700,000	215
1891	176,000	38,800,000	220
1892	181,000	40,500,000	224
1893	187,000	38,900,000	208
1894	193,000	39,300,000	203
1895	199,000	41,900,000	210
1896	205,000	45,200,000	220
1897	211,000	49,200,000	233
1898	218,000	.....	...
1899	226,000	.....	...
1900	234,000	.....	...

The quantity of water pumped has doubled in the last twelve years, and the quantity supplied per inhabitant has increased forty per cent. An estimate has been made of the population which may be expected in the district now supplied from the city water works, in the present city limits, and within a ten-mile radius of the City Hall. These estimates are as follows:—

Year.	In District now Supplied by City Water Works	In Present City Limits.	Within a Ten-Mile Radius from City Hall.
1890	171,000	243,000	503,000
1900	234,000	320,000	700,000
1910	320,000	420,000	980,000
1920	440,000	560,000	1,370,000
1930	600,000	740,000	1,920,000

If the consumption of water should keep pace with the increasing population and increase faster than the population, as it has been doing in recent years, a filter plant would require to be provided of enormous dimensions and prohibitive cost. Fortunately this is not the case. The experience of Pittsburgh is not different from that of other American cities which have supplied water at fixed rates and without limiting in any way the amount of water used and wasted by consumers. Under these conditions the volume of water pumped always increases faster than the population, and is only limited by the fact that after a time the cost of securing and distributing the water becomes so great as to make rational measures imperative.

Natural gas was formerly sold in Pittsburgh at a fixture rate, the amount charged for heating a house depending upon its size, etc. The practice has, however, been given up, and all gas is now sold by meter. The temptations to abuse the privilege of using water supplied at a fixture rate are quite as great as they are in the case of gas. In fact the opportunities are better, because gas cannot be discharged unburned into a house without making it uninhabitable, and if an excessive quantity of gas is burned, the house becomes too warm for comfort. There is thus a certain physical limit upon the amount of gas which can be used in a house. With water, however, this is not so. Faucets can be left open and leaks allowed to remain unrepaired, and the water allowed to flow to the sewers in absolutely unlimited quantities without benefiting any one. It has been found by careful and extended observation in both American and European cities that in the best class of modern houses an abundant supply of water for domestic purposes does not exceed from twenty to forty gallons per capita daily. Only in the very largest places, where many servants are kept, and much water is used for lawn sprinkling, do the quantities become as high as fifty or sixty gallons per capita daily.

As an average for American conditions, thirty gallons may be taken as a liberal allowance for all the water which can be used. The population now supplied with water from the Pittsburgh works is about 220,000. The quantity of water required to supply the needs of this population at thirty gallons per capita daily is 6,600,000 gallons. There were in manufacturing and business establishments, where meters were in

use during the last fiscal year, 692,000,000 gallons, and in other such establishments it was estimated by the assessors that 654,000,000 gallons were used. Assuming that the meters registered only two-thirds of the water in places where they are used, and that the assessors estimated only one-half of the water used in the remaining places, the water used in all manufacturing and business establishments was 6,400,000 gallons daily.

The amount of water used in schools, hospitals, public buildings, public fountains, for street sprinkling, etc., is rarely more than five gallons per capita daily. On this basis 1,100,000 gallons would be required daily for public purposes. Assuming further that there were unavoidable wastes of various kinds from the water works equal to the public uses, or 1,100,000 gallons, we have 15,200,000 gallons daily, or about sixty-nine gallons per capita as the amount of water legitimately used in the city of Pittsburgh. The amount pumped is more than three times this quantity, and it is a fair statement that two-thirds of the water now pumped is wasted without benefit to any one.

Various ways have been suggested for preventing the waste of water. One of these ways has been very much more successful than any other. This is the method which has been universally adopted for the sale of gas, namely, the use of meters. Under this system the water supplied to each consumer is measured and payment demanded according to the amount used.

There is often a prejudice against the use of meters, which arises from the thought that people will be limited in the use of water, and cannot use as much as they desire without making excessive payments for it. There is also the feeling that if the consumption of water in the city should be reduced to one-half or one-fourth of the present consumption, each person would have to get along with one-half or one-fourth as much water as is now used. As a matter of fact, this idea does not present even remotely the truth. A majority of people are reasonably careful in the use of water and do not waste excessive amounts. A majority of families in Pittsburgh probably use at the present time less than the amount of water mentioned in the above estimate. It is the minority of people, who, by carelessness or willful waste, discharge water into the sewers in large quantities, and increase enormously the amount of water which must be provided, and consequently the cost of water to all the people.

At the present time the loss inflicted by the careless or wasteful people is borne by the whole city. If a meter is put on every service, the people who waste water will have to pay for it, and others will be relieved from the burden, and the cost of water to them will be materially reduced. The cost to the people who are now wasting water will also be

reduced, if they are willing to learn by experience, as nearly all of them will, that they cannot waste water without paying for it.

The cost of installing a meter system is considerable, but it is very much less than the cost of installing the pumps, filters, reservoirs, and larger mains that will be necessary in case unrestricted waste is allowed to continue. The meter system also results in a saving in water rates to all people except those who under previous conditions are fraudulently or through carelessness securing quantities of water largely in excess of those to which they are entitled. I therefore most earnestly recommend that the city of Pittsburgh adopt forthwith the meter system, and I would make the following suggestions in regard to it:—

(1) That the city should own and set all meters, and assume all care of them.

(2) That the Superintendent should have the right to meter any service at his discretion.

(3) That all services should be metered commencing with the largest and those where unusual use or waste is thought likely to exist.

(4) That wherever a service is metered all water shall be paid for at meter rates, excepting that the sum charged shall not be less than three-fourths of the present fixture rates, and this sum shall be collected in all cases where less than a corresponding amount of water is used.

(5) That all schools, hospitals, and public institutions now supplied with water free or at a nominal charge, shall be metered; that the amount of water actually required by each shall be estimated by the Superintendent, and notice thereof sent to the respective institutions; and that in case water is drawn by any of them in excess of the amount thus allowed, the excess shall be paid for at the regular meter rates. In case of another city department, the excess shall be paid out of the appropriations of that department.

After the system has been so far introduced that the revenue derived from the sale of water is assured, the minimum rate should be reduced to one-half the fixture rate, or to such other amount as the financial condition of the water works will justify, and when all services are metered and the fixture rate is abolished, the minimum rate should be determined by a simpler schedule than the present fixture rate.

This arrangement will allow all parties taking water at fixture rates to save one-fourth of their present bills, and at the same time will assure the department an ample revenue to meet its present expenses, and the expenses of a filter plant when it is installed.

Cities Which Have Adopted the Meter System.

The meter system has been adopted and applied to all consumers by a number of European cities, notably by Berlin, and by a few American

cities, namely, Atlanta, Yonkers, and Madison. It has been adopted and applied to all services except the smaller domestic services by a much larger number of American cities,—Milwaukee, Providence, Syracuse, Worcester, Fall River, Hoboken, Lawrence, Manchester, Utica, Brockton, and Pawtucket have adopted in this way, and having more than half of their services metered. In addition to the above; New York, San Francisco, Kansas City, Lowell, Nashville, Toledo, Dayton, Des Moines, Peoria, Springfield, Quincy, Bay City, and Taunton have metered more than a quarter of their services, and nearly all cities which have started upon the introduction of the meter system are extending its use as circumstances permit.

Equitable Basis for Meter Rates.

The amount of money now obtained from the sale of water is about $740,000 per annum. This is on the basis of about fifty million gallons per day. With filters installed of this capacity, the operating expenses, interest and depreciation charges will amount to about $190,000 per annum. The cost of maintaining a meter system will not exceed $40,000.

The amount of money now raised by the water works is in excess of the operating expenses and interest and sinking fund charges for the water works. The balance is transferred to other city departments. Assuming that the works are to be maintained on a basis as profitable to the city as at present, the amount of revenue to be raised after the filter plant and meter system are installed, and with the quantity of water pumped as at present, is $970,000 per annum, or less than 5½ cents for every thousand gallons of water pumped.

It is found, however, that it is impossible to operate a water works system so that all of the water will be accounted for. In the best German practice, with all the services metered, sometimes as much as 90 per cent. of all the water pumped is accounted for. This, however, is rare, and has never been reached in American practice. Sixty per cent. is a good American average, and on this basis the average meter rate should be about nine cents per thousand gallons.

With very large consumers the rate should be somewhat less than for small consumers, and eight cents, or the present minimum rate, may be taken in these cases as not far from right, while the domestic rate must be maintained considerably higher on account of the greater slip in the small meters and waste and leakage from service pipes.

This basis, however, would not be a safe basis to assume in adopting the meter system. As I have shown, the greater part of the water pumped at the present time is wasted. With the meter system installed the consumption will be very much reduced, and consequently the revenue. A large part of the operating expenses, namely, the cost of

filtering and pumping, are nearly proportional to the quantity of water pumped, and will be reduced. The general administrative expense will not be reduced by reducing the consumption.

If the consumption should be reduced one-third at once, it is estimated that the operating expenses, including the operating expenses of filters, would be reduced by $120,000, leaving $850,000 to be derived from the sale of twelve billion gallons of water, or seven cents per thousand gallons. Assuming that the meters can be depended upon to register sixty per cent. of the water pumped, the meter rate upon this basis should average twelve cents per thousand gallons, and should be somewhat less for large consumers and somewhat more for domestic purposes.

Changing radically the system of charging for water invariably results in some uncertainty as to the amount of revenue to be derived from the new schedule, and to prevent the possibility of a deficit which might embarass the administration, I beg to suggest a rate of sixteen cents per thousand gallons for domestic purposes, and gradually reducing with increased quantities to the present minimum rate of eight cents per thousand gallons for the largest takers. In order to protect the city against serious reduction in revenue, in case the consumption should fall off more than is anticipated, the minimum rates are fixed at three-fourths of the present fixture rates, which will assure the city of a large revenue in any event, and will, at the same time, allow the takers to secure a twenty-five per cent. reduction in their present rates. It is necessary to allow them to save something, otherwise the objection to the change will be very great.

Cost of Installing Meter System.

There is a difficulty in estimating the cost of installing meters in Pittsburgh, on account of the very inadequate information regarding service pipes. People supplied with water from the city works are taxed according to the sizes of their houses, number of fixtures, etc., without regard to the manner in which they are connected with the city pipes. It will be necessary to have the service pipes straightened out in detail, and to know just what connections there are with the city pipes, and who is attached to each connection. In the absence of definite information regarding service pipes, only a rough estimate of the cost of meters can be made. Judging from the experience of other cities, and from such information regarding service pipes in Pittsburgh as can be obtained, the cost of installing meters on every service will be about $600,000.

In connection with the installation of meters, the service pipes should be given a thorough overhauling, and this may increase the expense

somewhat above the figure mentioned. This work should be done, however, whatever the cost, as the present system, or lack of system, in attending to the distribution of water cannot fail to result in great looseness in the use of water, and in heavy losses to the city, which losses, I believe, are far greater than the cost of putting the system in satisfactory condition. It will, of course, be impossible to do this work all at once. I would recommend that the work be begun at once, with an appropriation of $100,000 for the first year, and carried on as rapidly as circumstances will permit, the whole to extend over a period of perhaps five years. The saving effected in preventing waste of water and in securing the collection of revenue for water not now paid for, will fully pay for continuing the work, and no further appropriations on this account need be made.

With meters installed as recommended the consumption will stop increasing and will gradually diminish. A filter plant suitable for the present consumption will be sufficient to supply water to the population resident within the present water limits for a period of at least twenty-five years, or will be sufficient to supply water to the whole population of the city, including those wards now supplied by water companies, for at least fifteen years.

Should the present unrestricted use of water be allowed to continue, a filter plant as proposed will have been outgrown almost before it is completed, and additions will require to follow each other on a scale and with the frequency which can hardly be estimated.

SUPPLY OF THE SOUTH SIDE WITH FILTERED WATER.

That part of the city of Pittsburgh south of the Monongahela River, and having an estimated population of about 78,000, is supplied with water by the Monongahela Water Company. As has been stated above, the Allegheny is in every respect a more desirable source of supply than the Monongahela River, and, from an engineering standpoint, it would be better to supply this part of the city with water from the Allegheny than to attempt to filter the water of the Monongahela River. The filters included in the above estimates are of sufficient capacity to supply the whole of the city, including the South Side, in case the meter system is introduced. In case the meter system should not be introduced, the quantity of water required would be much greater, and to meet the present consumption of the whole city a filter plant would be required costing about $2,600,000; and to meet the estimated consumption in 1910 without meters, namely, 116,000,000 gallons, a plant would be required costing over four million dollars. I have not considered this question further, as arrangements for it, either by the city direct or through the Monongahela Water Company, involve questions not of an engineering nature.

GRAVITY SOURCES.

The country about Pittsburgh is rolling, with a general slope downward toward the west, and there is no land in the immediate neighborhood of the city high enough to yield a gravity supply of water. There are valleys in the Allegheny mountains east and south of the city high enough so that water from them could be taken by gravity to Pittsburgh. The nearest water-sheds of this kind are those of certain tributaries of the Youghiogheny and Kiskiminetis Rivers among the foot hills of the mountains. Of these the most promising one which we have found is the water-shed of Indian Creek. Indian Creek enters the Youghiogheny River eight miles beyond Connellsville. Laurel Hill Creek, immediately beyond Indian Creek, has a smaller water-shed and is farther from Pitsburgh. The Loyalhanna above Ligonier, the next water-shed to the north of Indian Creek, has not a sufficient drainage area above the town, where only it could be taken.

Farther away, beyond Laurel Ridge, the Conemaugh River at Johnstown has a sufficient drainage area and a sufficient elevation. Its valley is occupied by the Pennsylvania Railroad, which would make the construction of an adequate reservoir difficult, if not impossible. Stony Creek, south of Johnstown, is also sufficient in size and elevation, but its valley is occupied by the Baltimore & Ohio Railroad. The distances from Pittsburgh are also greater than the distance from Indian Creek.

South of Indian Creek and Laurel Hill Creek are the Castleman, the Youghiogheny and the Cheat Rivers. Any of these could be taken at points high enough to flow to Pittsburgh by gravity. It has been suggested that the water from one of these streams might be brought to Pittsburgh through a conduit. It is doubtful if the flows of any of them could be depended upon at all times to yield a sufficient quantity of water for Pittsburgh without storage reservoirs. With moderate sized storage reservoirs any of them would be ample. All these streams have rapid currents, and during heavy rains they become very muddy, although the turbidity disappears quickly afterward. If these waters should be brought to Pittsburgh without sedimentation, or with only such sedimentation as could be secured in a comparatively small reservoir through which the flood currents would have to be allowed to flow, the city would suffer in only less degree from mud than it now does. All projects of this nature have therefore been dismissed, and in case any of these streams should be utilized, it must be in connection with adequate storage reservoirs, and when so considered the cost would become much greater than that of a supply from a storage reservoir on Indian Creek.

Indian Creek.

The Western Water Company had acquired certain property upon Indian Creek, and had made certain investigations in regard to its development for water supply purposes, and this information has been put at our disposal by officers of the Company. In case the city should decide to secure its water in this way, it would have to acquire the property of the Western Water Company, together with such other real estate as might be necessary.

Preliminary examination indicated that many of the conditions were favorable for securing a water supply from this source. The services of Mr. Emil Kuichling, Chief Engineer of the Rochester Water Works, and an engineer of large experience in water works construction, were secured to investigate more in detail the possible development of this supply, and he has made a report thereon with estimates of cost, which I transmit to you herewith. You will find in it a description of the project, and estimates in greater detail.

Chief Features of the Project.

This project involves the construction of a conduit line, from the reservoir to Pittsburgh, a distance of forty-seven miles, forty-two miles being steel pipe, and five miles tunnel. The dam required would be higher than any dam yet constructed. The water in the new reservoir would be 238 feet above the present stream, and the total height of masonry would be 270 feet.

The highest dam yet constructed or undertaken is the new Cornell dam for the water works of the city of New York, in which the water line of the finished reservoir will be 149 feet above the original water level, and the extreme height of masonry will be about 290 feet. The general height will be considerably less. The Indian Creek reservoir would have an area of 2,000 acres, and a capacity of forty billion gallons.

Quantity of Water.

The quantity of water which can be developed from the Indian Creek water-shed is estimated at ninety-two million gallons daily. By adding Laurel Creek the supply could be increased to an amount which is estimated at one hundred and thirty million gallons daily.

The flow of Indian Creek in summer is much less than the amount above estimated. The project involves the construction of a dam large enough to hold a year's supply of water when the city is using seventy-five million gallons daily, and the heavy winter and spring flows would be stored and made available during those months of the year when the flow of the stream is less. The dam is also large enough to hold some of the water of wet years and allow it to be drawn in dry years.

Quality of Water.

The water would be very soft; softer than the Allegheny River water. It would be nearly colorless. Under some conditions it would be subject to disagreeable tastes and odors, although it is hardly probable that these conditions would be of frequent occurrence or would become generally offensive. As there is but comparatively little population upon the water-shed, and that of such a nature as to admit of ready control, and owing to the purifying actions which take place in very large reservoirs, the water would compare favorably with the best water supplies of the country in quality, and in its natural state would be equivalent in purity to the Allegheny River water after filtration.

Difficulties with Coal Lands.

The pipe lines from the reservoir to the city would pass over many miles of coal fields. As the coal is removed settlements occur, and there would be danger that the pipes might be broken and the supply cut off. For this reason it is not considered safe to use a single line of pipe, but the estimate is for two independent lines, connected at selected points on solid ground, so that in case of a break in either line, all of the water could be sent through the other line until the break could be repaired.

Cost of Work.

The total cost of works for the introduction of water from Indian Creek is estimated at $13,568,500. This provides two lines of pipe capable of delivering together seventy-five million gallons per day. Owing to fluctuations in the daily consumption, it would not be safe to depend upon these pipes after the average consumption reached sixty-five million gallons, and at that time a third pipe would have to be added. When the average consumption reached ninety-two million gallons per day, additonal water sources would have to be added. Laurel Hill Creek is the most obvious source to be taken for this purpose, and estimates have been made of the cost of adding Laurel Hill Creek to the system, and of adding a fourth pipe line to the city. These last estimates are less accurate than those relating to Indian Creek, because of less complete data regarding Laurel Hill Creek.

COMPARISON OF THE COST OF A GRAVITY SUPPLY AND THE PRESENT SUPPLY FILTERED.

I have prepared a diagram showing the annual charges for a gravity supply and for the present supply filtered, first, upon the supposition that the meter system will be adopted, and, second, upon the supposition that it will not be adopted, and that the consumption will increase

gradually to 300,000,000 gallons per day, which diagram is presented herewith.* The charges included in this diagram represent all costs of delivering the water into the distributing reservoirs.

For the gravity supply these charges are made up as follows:— Interest is reckoned at 3.25 per cent. on the total expenditure. For the cost of the steel pipe lines, sinking fund payments are taken at 1.326 per cent. of the cost, sufficient with compound interest to replace the pipes at the original cost at the expiration of forty years. Sinking fund payments on all the rest of the expenditures are taken at 0.6133 per cent., sufficient to provide for the payment of bonds at the expiration of sixty years. To these sums are added maintenance expenses, amounting to $14,000 per annum.

These charges amount to $582,500 per annum, with the original plant, which will suffice until the average consumption reaches sixty-five million gallons daily. They will then be increased with the third pipe line to $722,300 per annum, and will then remain constant until the consumption reaches ninety-two million gallons daily. With the addition of Laurel Hill Creek and a fourth pipe line, they will be increased to $978,000, and will then remain constant until the consumption reaches one hundred and thirty million gallons per day, after which new supplies will have to be found.

In computing the amount of water required, it is assumed that the wards now supplied by private water companies will be supplied from the city works after 1905. The exact date is not of material importance in the estimates. The relative costs would not be materially changed if it should be taken a few years earlier or later.

The costs of maintaining the present supply and of filtering it are computed as follows:—The total cost of maintenance of filters, including interest, depreciation, and operating expenses under the first scheme, page 66, are taken at $192,184 per annum. To this is added the cost of pumping the water from Brilliant to the distributing reservoirs. The present cost is $8.00 per million gallons, and when the new reservoir is completed it may be estimated that one-half of the water will be pumped to it at a cost of $6.00 per million gallons. The total cost of pumping will then average $7.00 per million gallons, or $127,750 per annum for fifty million gallons daily. To this must be added an allowance for the depreciation of the machinery at the Brilliant pumping station, which is estimated at $22,000 per annum, making a total annual cost of $342,000 for fifty million gallons of filtered water per day delivered in the reservoirs. No allowance is made for interest on the cost of the Brilliant pumping station, as the city now owns it, and no further capital outlay is required in connection with it as long as the consumption does

* See Plate No. 10, opposite Page 84.

not exceed the amount mentioned. Renewals are provided for in the charge for depreciation.

For consumption in excess of fifty million gallons per day the costs of construction and operation are taken as increasing in proportion to the quantity filtered, but with no addition for land and certain structures provided in the original estimate, large enough to allow the plant to be doubled; and it is further assumed that additional pumping machinery will be required at Brilliant, on which the interest as well as the depreciation is reckoned. The annual charges computed in this way amount to $342,000 for fifty million gallons daily, and $6,700 per annum for each additional million gallons.

No account has been taken of the fact that some of the bonds would be ultimately retired by the sinking fund charges, and interest thereby reduced. On the more perishable parts of the plants depreciation only has been reckoned, and it is assumed that this depreciation would replace the parts when necessary and that the indebtedness would remain the same. Should it be inexpedient to renew them for any reason, however, the accumulated depreciation charges would suffice to pay off the outstanding bonds. On the more permanent parts of the plant sinking fund charges have been taken sufficient to retire the indebtedness after forty years for the filtered supply and after sixty years for the gravity supply. No reduction in capital expense could then be expected within these periods.

It is estimated that filters could be put in service two years earlier than the gravity supply, construction being commenced at the same time, and the charges are assumed as increasing from nothing to the full amount at a uniform rate during the period of construction, as plotted in the diagram.

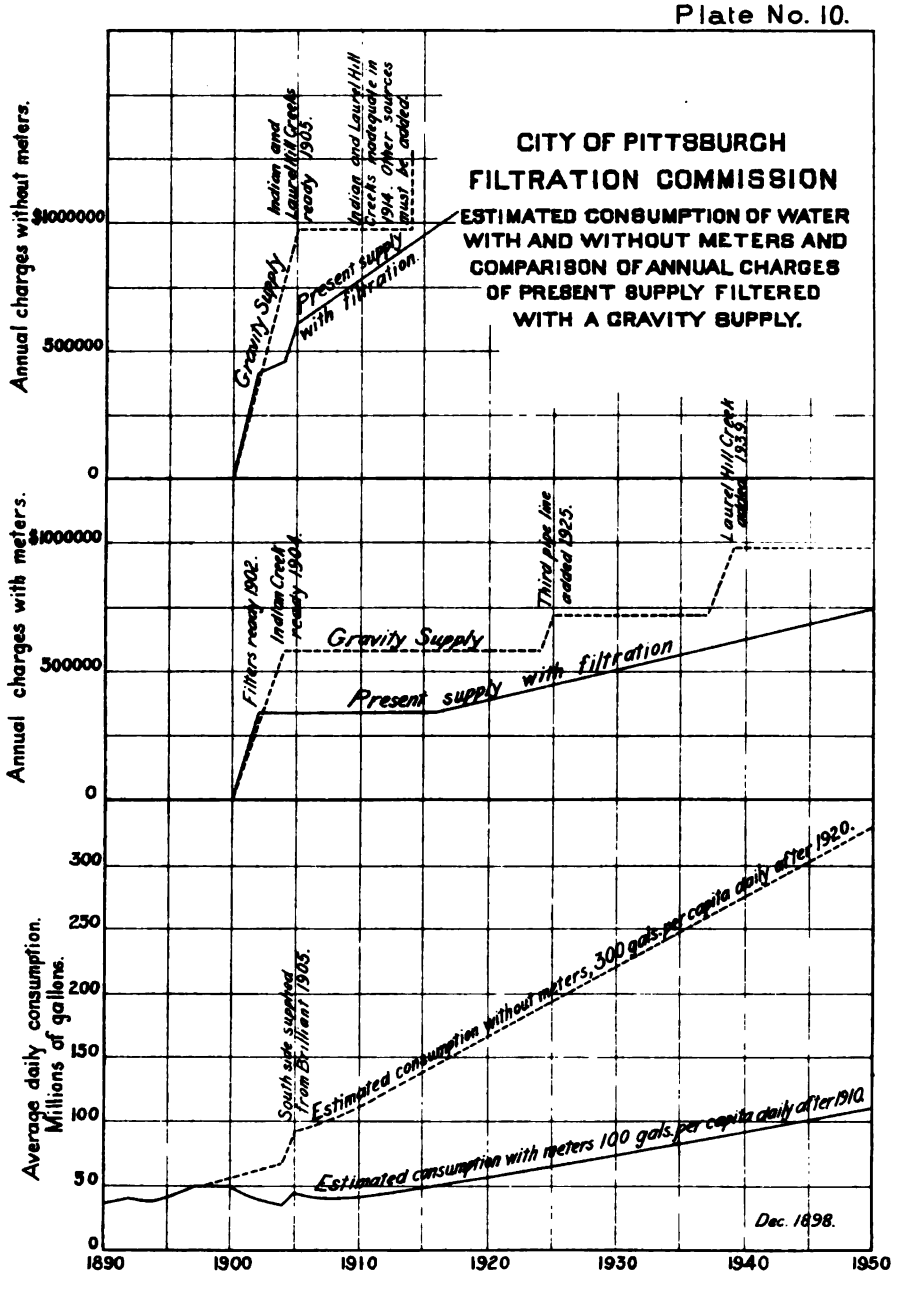
Comparison of Costs.

Comparing the aggregate annual charges for the two systems with meters, we have:—

	Estimated Population Last Date.	AVERAGE ANNUAL CHARGES. Gravity Supply.	Present Supply with Filtration.	Excess of Cost of Gravity Supply; Per Cent.
1900 to 1910.....	420,000	$460,000	$300,000	53
1910 to 1920.....	560,000	582,000	347,000	68
1920 to 1930.....	740,000	652,000	444,000	47
1930 to 1940.....	920,000	768,000	562,000	37
1940 to 1950.....1,100,000		972,000	682,000	43

The aggregate estimated charges for fifty years are thirty-four million dollars for the gravity supply, and twenty-three million for the present supply with filtration. The gravity supply will thus cost in that time forty-eight per cent. more than the present supply with filtration.

Plate No. 10.


CITY OF PITTSBURGH
FILTRATION COMMISSION
ESTIMATED CONSUMPTION OF WATER WITH AND WITHOUT METERS AND COMPARISON OF ANNUAL CHARGES OF PRESENT SUPPLY FILTERED WITH A GRAVITY SUPPLY.
Annual charges without meters.
$1000000
500000
0
Gravity Supply
Present supply with filtration.
Indian and Lowry Hill Creeks ready 1903.
Indian and Lowry Hill Creeks inadequate in 1914. Other sources must be added.
Annual charges with meters.
$1000000
500000
0
Filters ready 1902.
Indian Creek ready 1904.
Gravity Supply
Present supply with filtration
Third pipe line added 1925.
Laurel Hill Creek added 1938
Average daily consumption. Millions of gallons.
300
250
200
150
100
50
0
South side supplied from Brilliant 1903.
Estimated consumption without meters, 300 gals. per capita daily after 1920.
Estimated consumption with meters 100 gals. per capita daily after 1910.
Dec. 1898.
1890
1900
1910
1920
1930
1940
1950

An important difference between the schemes is the way in which money is required. In the gravity scheme the capital expenditure must be met practically all at one time whether the full amount of water is wanted or not. With filtration and pumping the capital expenditure required at first, although considerable, is only a sixth of that required for the gravity scheme, and the operating expenses are only incurred as water is required, and in proportion to the amount needed. With the gravity scheme it is obvious that the only admissible procedure is to construct a dam and tunnel capable of delivering the whole available supply of the water-shed at one operation. This entails a heavy burden for interest and sinking funds for a long period of years.

With the filtration and pumping scheme, on the other hand, only so much money need be spent as will provide a supply for the immediate requirements of the city, and further expenditure need be made only as the growth of the city demands it. If the regulations regarding the sale of water suggested to you should be adopted, no extensions will be required for a long period of years, and the charges under the filtration scheme will be much less than under the gravity scheme.

The Indian Creek scheme is certainly not to be carried out in a less complete manner than that contemplated in our estimates. It would never do to have to cut a second tunnel through the mountain, or to raise a dam of the magnitude of the one which must be built in any event, or to have the city left without water by a break in a single pipe line. To carry it out as estimated requires an expenditure of money at once which would load the city of Pittsburgh with a debt which the city ought not lightly to assume. On the other hand, the pumping and filtration scheme can be proceeded with at an expenditure so moderate that all charges can be readily met from the income of the department without embarrassing the city in any way.

CONCLUSIONS AND RECOMMENDATIONS.

I have shown that your present water supply is seriously objectionable, because of the mud which it carries, and because of the polluting matters which enter the river. By filtration the mud and the effects of pollution can be effectively removed.

It is feasible to introduce a gravity supply of excellent water from practically unpolluted sources, but the cost of doing it will be six times as great as the cost of installing filters. The operating expenses of filters are greater, but allowing for them, the cost of the gravity supply is much greater than the cost of your present supply with filtration. I therefore recommend that the present supply should be continued in use, and that it should be filtered.

Two methods of filtration have been examined, either of which is capable of furnishing at all times sufficient water free from mud or objectionable turbidity. Of these systems, one, namely, sand filtration, removes more completely the effects of pollution than does the other, namely, mechanical filtration. I therefore recommend the adoption of sand filtration.

The city is now wasting several times as much water as it uses. The experience of other cities shows that the consumption can be greatly reduced by the adoption of the meter system for the sale of water, and the cost of filtration and pumping can be kept within reasonable limits. I recommend the adoption of the meter system.

A filter plant suitable of supplying an annual average consumption of fifty million gallons per day, and with a maximum capacity one-half greater, will supply the whole city, including those wards not now supplied from the city works, until the population of the city reaches half a million.

The general arrangement of such a plant has been indicated in connection with the estimates for the various filter projects. It would consist of a pumping station on the north side of the river, pumping water to sedimentation basins holding fifty million gallons, from which it would flow to open sand filters with an effective filtering area of twenty-five acres; thence to a covered pure water reservoir, and thence through a tunnel under the river to the Brilliant pumping station. The cost of constructing such a plant, with all accessories complete, is estimated at one million, six hundred and ninety-one thousand (1,691,000) dollars. To this must be added the cost of the necessary land, which is estimated at four hundred and twenty thousand ($420,000) dollars, and an appropriation of one hundred thousand ($100,000) dollars for commencing the work of installing meters.

The total estimated cost of carrying out the works now recommended is two million, two hundred and eleven thousand ($2,211,000) dollars.

I believe that this is the best way for the city of Pittsburgh to supply itself with good, wholesome, and clear water, and I recommend its adoption, and that the necessary arrangements for carrying it into effect be adopted.

Respectfully submitted,

ALLEN HAZEN.

January 9, 1899.

REPORT

UPON A

Gravity Water Supply

FROM

INDIAN CREEK.

BY

EMIL KUICHLING, C. E.

EXHIBIT 3.

ALLEN HAZEN, ESQ., C. E.,
Consulting Engineer,
Pittsburgh Filtration Commission.

DEAR SIR:—

In response to your request for a brief account of my investigations of the plan for supplying the city of Pittsburgh, Pa., with an adequate quantity of potable water by gravity from Indian Creek, I beg leave to submit the following general report:—

Source.

The source of the contemplated supply is Indian Creek, which flows into the Youghiogheny River at a point about 42 miles southeasterly, in an air line, from Highland Park Reservoir. This creek lies between the two ranges of mountains called Chestnut Ridge and Laurel Hill, and is doubtless the nearest available source from which a sufficient volume of good water can be delivered by gravity alone into said reservoir. Unfortunately, the mouth of the stream is nearly 100 feet below the level of said reservoir, but its bed rises quite rapidly as we proceed up the valley a few miles, until it attains an elevation of about 80 feet above said reservoir at a point about one mile above Resler's Run, and near the small village of Springfield. Beyond this point, the general slope of the valley is somewhat less, and the creek follows a tortuous course through a series of alluvial flats which have formed at the foot of the mountains.

As the entire drainage area of Indian Creek is only about 125.7 square miles, and the natural flow of the creek in periods of drought is probably much less than the present water consumption in the city, it is obvious that the availability of this source must be contingent upon the construction, somewhere in the valley, of a capacious storage reservoir; also that the elevation of the water surface therein, when drawn to its minimum level, shall be such as to give an ample fall, in a distance not less than 43 miles, to Highland Park Reservoir. Assuming for this fall a grade of about 5.6 feet per mile in an economical steel pipe conduit, it follows that the aforesaid minimum water level in the Indian Creek storage reservoir must be at least 240 feet above the said city reservoir, or at an elevation of at least 1,310 feet above sea level. On examining the topographical map of the valley, however, it will be found that this elevation in the bed of the stream occurs at a point about 4 miles above the locality mentioned in the preceding paragraph, and also that the

drainage area at said point is only about 93 square miles, while at the first-named place it is 112.2 square miles.

The elevation of the high-water level in the storage reservoir, on the other hand, is dependent upon the volume which must be impounded and the average area of the water surface. As will be shown below, this volume should safely be about 27,400,000,000 gallons, which can be represented by a stratum 84 feet thick with an average area of 1,000 acres, or by one of 42 feet thickness, with an average area of 2,000 acres. Such large areas and volumes, however, are difficult to obtain in a relatively narrow and steep valley like that of Indian Creek, without a very high dam; and as the ultimate cost of the project is largely influenced by the dimensions of such a structure, it will be seen that its proper location involves many careful computations for a variety of different sites. For want of time, only three such sites have thus far been considered, and their study has resulted in the provisional selection of the dam site at a point in the valley about one mile above the mouth of Resler's Run, where the elevation of the creek's bed is about 80 feet above Highland Park Reservoir, or 1,150 feet above sea level.

The drainage area above this site is about 112 square miles. From the best available data, it is estimated that 40 per cent. of this surface is cleared land, while the remaining 60 per cent. is forest and brush. As there are no coal seams or other minerals here which can be worked profitably, the land is used only for farming and timber purposes; hence it is found from the census of 1890 that the entire population on said area, which embraces parts of the townships of Springfield and Salt Lick, in Fayette County, and part of Donegal in Westmoreland County, does not exceed 3,300, or an average density of 30 per square mile. A few hamlets, such as Springfield, Mill Run, Indian Head and Jones Mills, occur on the water-shed, but with the exception of Mill Run, they will not be affected by the storage reservoir, nor will their presence be of moment to the latter from a sanitary point of view.

Without entering upon a description of the various geological strata which appear in the bed of the creek and sides of the valley, it may briefly be stated that no coal seams are known to exist below the site selected for the dam, and that the underlying rock is mostly a hard sandstone, with an occasional layer of hard limestone; while above said site, the rock appears to be chiefly a durable sandstone up to the coal deposits, where shales overlaid by sandstone, etc., are found. So far as could be determined within the available time, the coal is generally above the high water level of the proposed reservoir, and hence the latter will not interfere materially with future mining operations, if such should ever be undertaken on a large scale. It is therefore extremely probable that an excellent foundation for a high masonry dam can be

secured without difficulty, and that an ample supply of suitable material for making such a dam can be obtained from conveniently situated quarries.

From the character of the rocks, and the entire absence of any deposits of glacial drift, it may be inferred that the surface soil is of a sandy nature, as is in fact the case. For this reason, the water which is yielded by such a drainage area will be very soft, and when stored in a large reservoir it will soon become very clear. With proper precautions to prevent the inflow of surface drainage waters in the vicinity of the inlet to the conduit, the delivery of water can be assured which will usually be perfectly clear, and will be affected only in times of freshet by a slight degree of turbidity due to mineral matter. It may, however, be anticipated that the large proportion of timber land on the water-shed will supply the water with more or less vegetable organic matter, which may occasionally impart to it a slight color, along with a disagreeable odor and taste, due to the development of certain minute aquatic plants, such as are found in all natural lakes or ponds; but as these conditions occur only at long intervals, and last only for a short period of time, an objection on this account to such a source of potable water supply cannot be regarded as well founded.

Taking all the conditions into account, as briefly outlined above, it is fair to conclude that the source under consideration is excellent, and that the quality of the water taken therefrom will compare favorably with the best public supplies now in existence.

Available Quantity.

As mentioned in the foregoing, the drainage area above the site of the proposed dam is 112 square miles, and the question now arises as to the quantity of water which may be collected therefrom. Obviously this depends chiefly upon the magnitude and seasonal distribution of the rainfall; and as no systematic gaugings of Indian Creek have ever been made, we can only apply to this water-shed the results of long-continued observations of stream discharge in other similar drainage basins which receive practically the same amount of rainfall. A brief reference to the latter is therefore necessary.

So far as can be learned, the only gaugings of the rainfall on the Indian Creek basin, are those which were made by agents of the Western Water Company during the four years from 1893 to 1896, inclusive, and which exhibit an average precipitation of 35.65 inches, with a minimum of 31.11 inches in 1894. The rainfall at a number of stations around this basin has, however, been observed more or less regularly and carefully for some years past, and the data have been published in the Report of the Secretary of Internal Affairs of Pennsylvania for the year 1895,

and subsequently in the reports of the U. S. Weather Bureau. From these documents, the data relating to the following nine stations, nearest to and surrounding the Indian Creek basin have been compiled and studied along with the records relating to the latter:—

No.	STATIONS.	Period.	Number of Years.	Average Yearly Rainfall, Inches.	Minimum Rainfall, Inches.	Year of Minimum Rainfall.
1	Johnstown, Cambria Co.....	1885-95	11	46.07	37.55	1895
2	Stoyestown, Somerset Co.....	1891-95	5	44.47	40.29	1892
3	Somerset, Somerset Co.....	1888-95	8	48.44	31.48	1895
4	Confluence, Somerset Co.....	1875-95	21	44.45	35.11	1895
5	Uniontown, Fayette Co.....	1888-95	8	49.51	38.65	1895
6	Greensborough, Greene Co.....	1889-95	7	42.99	33.76	1893
7	Lock No. 4, Washington Co.....	1886-95	10	40.74	24.88	1895
8	W. Newton, Westmoreland Co...	1891-95	5	34.34	29.57	1895
9	Lycippus, Westmoreland Co.....	1893-97	5	41.34	31.85	1895
10	Indian Creek, Fayette Co.....	1893-96	4	35.65	31.11	1894
	Averages		8.4	42.80	33.42	....

According to the foregoing table, the average yearly rainfall of the Indian Creek region is 42.80 inches, with an average minimum of 33.42 inches in the driest year; but it must be remembered that the periods for most of the stations embrace only a few years, and hence it is fair to presume that the true average will be somewhat greater than 42.80 inches, and similarly, that the minimum at Indian Creek will be somewhat less than the record of 31.11 inches in 1894. On comparing these figures with the precipitation records of other drainage basins where the stream flow or run-off has been regularly and carefully measured for many years, it will be found that they agree best with those of the Sudbury River, near Boston, Mass.; and as this water-shed is classed among those which yield the smallest percentage of the precipitation as stream flow, it will be prudent to base our computations for storage and run-off upon the data relating thereto.

These data are essentially as follows:—Area of water-shed, 75.2 square miles in a hilly and rocky region; mean annual rainfall for 23 years, from 1875 to 1897, inclusive, 45.77 inches; least rainfall for one year, 32.78 inches in 1883; average depth of rainfall collected yearly or running off in the river, 22.22 inches; least depth of rainfall collected, 11.19 inches, in 1883. From these records, which are considered to be the most complete and carefully kept in this country, Mr. Frederic P. Stearns, the Chief Engineer of the Boston Metropolitan Water Board,

has prepared a table showing the storage required per square mile of water-shed for different rates of draft in gallons per day, in order that the reservoir will not become empty in times of long-continued drought; and by applying this table to the case under consideration, the necessary capacity of the proposed reservoir can readily be determined.

For this purpose, it will be assumed that the draft will be 75,000,000 gallons per day, and that the area of the Indian Creek water-shed above the dam is 112 square miles, of which about 3 per cent., or 3.28 square miles (2,100 acres) is water surface, while the remaining 108.72 square miles is land surface. The said draft is at the rate of 690,000 gallons per square mile of land surface per day, and according to Mr. Stearns' table this requires a storage of 148,200,000 gallons per square mile of such surface, or a total of 16,112,300,000 gallons, which represents a supply of 75,000,000 gallons per day for 195 days, on the supposition that no rain whatever falls on the water-shed, and that the reservoir loses by evarporation during this period a depth of 30 inches on an average area of 1,800 acres.

In view of the rapid growth and enormous water consumption of Pittsburgh, however, and also the contingency that in a year of extreme drought the rainfall may be so distributed as to yield even less than has been experienced on the Sudbury River basin, it will be expedient to consider that the effective storage volume shall be at least 50 per cent. greater than the above figures, or about 27,400,000,000 gallons. This represents 346 days' supply at the rate of 75,000,000 gallons per day, or 282 days' supply at the rate of 92,000,000 gallons per day, or 173 days' supply at the rate of 150,000,000 gallons per day, without any rainfall, and allowing for evaporation as before; and it also represents what is required, according to Mr. Stearns' table, for a daily supply of 92,000,000 gallons from the water-shed. Another reason for referring particularly to this latter quantity, is that it represents the safe average capacity of three conduit pipes to the city, as will be explained in further detail below.

This storage may certainly be regarded as ample for the relatively small drainage area of Indian Creek; but as it is entirely feasible in the future to supplement the yield of this basin by the flow from the adjacent area of 105 square miles of Laurel Hill Creek, it may be proper to retain it for the purpose of making an estimate of the probable cost of the work. Obviously the dimensions of the dam will thereby be considerably increased, but the value of the work to the city will be in much larger proportion. To indicate what is involved in this larger storage, it may be mentioned that the height of the dam is thereby increased about 19 feet, its volume about 110,000 cubic yards, and its cost about $600,000; hence to compare the resulting cost of this scheme with that of another similar project which provides for an ultimate storage of only 16,112,-

300,000 gallons, said increased cost should be deducted from the subjoined estimate.

A few words may also be added here in relation to the possible supplementary supply from Laurel Hill Creek, mentioned in the preceding paragraph. It appears from the surveys and maps submitted by the Western Water Company, that such a supply will require the construction of a reservoir and dam of relatively moderate dimensions in this valley, from which a tunnel conduit about 39,600 feet, or 7.50 miles long, will convey the water thus collected into the proposed large Indian Creek Reservoir. At the site of said dam, the Laurel Hill Creek valley is much wider and the hillsides have easier slopes, than is the case at Indian Creek, so that a high structure with great storage capacity will be correspondingly more expensive. It is therefore suggested that said dam shall be adequate for only a partial development of the water resources of the drainage area, and that in times of freshet the surplus be allowed to escape. On this basis, the two water-sheds taken together may be regarded as capable of affording the city a safe ultimate supply of about 130,000,000 gallons per day during the driest three consecutive years for which data are available; and it may also be remarked that this is the longest period of time which experience has shown need be considered in dealing with public water supplies.

Owing to the lack of sufficient topographical details relating to the Laurel Hill Creek basin, it has been impossible to make an accurate estimate of the cost of the supplementary dam and reservoir mentioned, but from the data afforded by other similar works, it is believed that the sum of $1,300,000 will suffice to provide all that may be needed in this direction, while $1,700,000 will be required for the long tunnel to the Indian Creek Reservoir. The cost of the partial development of the Laurel Hill Creek basin may therefore be estimated at about $3,000,000; and in contrast thereto it may be mentioned that the estimate for the Indian Creek Reservoir and appurtenances is about $5,480,000, exclusive of any conduit work.

Consumption.

It has been assumed in the foregoing that the proposed gravity works shall be capable of delivering at least 75,000,000 gallons per day, inasmuch as the present consumption in the city, during seasons of greatest draft, has nearly reached this amount. Taking the entire estimated population at 300,000, we thus obtain the enormous rate of 250 gallons per head per day, which is practically twice as much as is commonly regarded a very liberal allowance in other large cities. From a recent compilation of the water consumption in 100 American cities of over 30,000 inhabitants, which embraces every large city in the Union,

and an aggregate population of about 16,600,000, it is found that the average is 112 gallons per capita, and that if classified according to population, the averages are as follows:—

For cities of from	30,000	to	100.000	inhabitants,	105	gallons	per head.
" "	100,000	"	300,000	"	106	"	"
" "	300,000	"	600,000	"	122	"	"
" "	600 000	"	2,000,000	"	116	"	"

This statement renders it clearly evident that the large consumption in Pittsburgh is highly abnormal; and if the fact that many of the large industrial establishments in the city are provided with independent supplies from the two rivers is taken into account, the conclusion cannot be resisted that much of this excessive use of water from the public mains is due to preventable waste. When it becomes necessary for a city to obtain a good gravity supply from a locality so far distant as Indian Creek, such a large consumption will inevitably lead to a great outlay for construction and fixed annual charges, and the utmost restriction of waste should become the rigid policy of the municipal administration. With such measures properly enforced, the daily consumption may readily be reduced to an average of 45,000,000 gallons, in which event the provision of a delivery of 75,000,000 gallons per day from the gravity conduit will be ample for a considerable term of years, or until a population of at least 400,000 is reached.

It may be remarked in this connection, that the ultimate capacity of a gravity conduit must not be taken as the measure of the average daily consumption in a city, as unavoidable increments in rate of use usually occur at different seasons which, if continued for too long a time, will exhaust the available supply in the distributing reservoir, and thus lead to various dangers. From the experience of other cities, it has beeen found that where the distributing reservoir holds only a few days' store of water, the average daily consumption should not exceed 87 per cent. of the ultimate capacity of the gravity conduit; or expressed conversely, the seasonal increments of the consumption should not exceed 15 per cent. of the average daily use throughout the year. When this limit has been attained, an additional supply must soon be provided in order that the possibility of a water famine may be averted. On this basis, an ultimate conduit capacity of 75,000,000 gallons per day corresponds to a daily average use of about 65,000,000 gallons, which should be a very liberal supply for a city of 435,000 inhabitants.

The growth of the city will, however, doubtless continue after the said population has been attained, and hence any adequate plan for a gravity supply must take such future growth into account, as was indicated in the foregoing description of the Indian Creek basin and its probable capacity. The same comment is also applicable to the conduit,

which should obviously be designed so as to admit of subsequent increments to the initial supply without materially interrupting its regular discharge. These essential points have been duly borne in mind in the following formulation of the Indian Creek project; and to present the same in definite terms, it will be assumed that the legitimate use of water in the city for all purposes can readily be reduced to an average of 150 gallons per capita per day, and that with its present estimated population of 300,000 and an average daily consumption of 45,000,000 gallons, an initial conduit capacity of 75,000,000 gallons per day will afford ample provision for growth during a period of from 10 to 20 years.

Storage Reservoir and Dam.

In the foregoing it was found that with a drainage area of 112 square miles, and a dam of sufficient height near the village of Springfield to afford an available or effective storage of 27,400,000,000 gallons, the Indian Creek basin can safely be depended on to yield a daily supply of 92,000,000 gallons; and that by diverting into the large reservoir thus formed a portion of the water collected from 105 square miles of the adjacent Laurel Hill Creek basin, the daily supply can be increased to about 130,000,000 gallons. It was also found that a constant and regular draft of 75,000,000 gallons per day from the Indian Creek basin alone, requires a reservoir with an effective storage capacity of 16,112,300,000 gallons. The last-named draft, however, affords insufficient provision for future demands; and as comparatively little is gained by stopping the construction of such a dam temporarily at a lower level, with the expectation of raising its crest in the future, it will be expedient to finish the construction at once to its full height. In view of the magnitude of the undertaking, and to allow ample margin for subsequent increments of draft, the first-named effective storage volume of 27,400,000,000 gallons has been adopted as being a close approximation to that which further study may demonstrate to be the most advantageous.

It was also shown that, on account of the great length of the conduit from Indian Creek to Highland Park Reservoir, the elevation of the lowest water level in the storage reservoir should not be less than about 1,310 feet above sea level. At this elevation, however, a large extent of alluvial flats will become exposed, and to avoid the resulting undesirable effects, the low-water level has been taken at the elevation of 1,320 feet above sea. The area of the reservoir at this level will be about 848 acres; its greatest depth of water at the dam will be about 175 feet, and it will contain about 13,150,000,000 gallons, which will not be available for use, since the effective storage capacity must lie

wholly above said level. As the latter is 27,400,000,000 gallons, the spillway level must be sought at an elevation corresponding to a total impounding capacity of 40,550,000,000 gallons, which is found at or near elevation 1,383 feet above sea; here the area of the water surface will be about 1,912 acres, and the greatest depth of water at the dam will be about 238 feet.

Obviously, the adoption of any other structure than a masonry dam of the most massive description, for impounding such an enormous volume and depth of water, is not to be considered, and to compute the quantity of masonry needed for the purpose, the dimensions established by the engineers of the new Croton River Dam, now in process of construction near Yonkers, N. Y., have been adopted. From these computations and the preliminary sketch plans, it was found that the dam and its appurtenances will require about 605,000 cubic yards of various classes of masonry, exclusive of the rough stone work needed for bank protections, etc., and the better class of work for the superstructures of the valve houses. It may also be mentioned that these figures are based on the assumption that a suitable rock foundation will be secured at moderate depth below the existing surface, as will doubtless be the case.

The large reservoir thus created will manifestly interfere with the public highways that now pass through and across the principal valleys, and hence the estimate must include the cost of such new roads and bridges as may be necessary to restore the means of communication in the district affected. A considerable quantity of land bordering on the flow line all around the reservoir must also be acquired by the city in order to prevent any direct pollution of the water, and more or less work must likewise be done on private premises beyond the aforesaid marginal area, to insure the purity of the numerous tributaries. Provision has accordingly been made in the estimate for the purchase oi at least 3,100 acres of land in the valley, including the reservoir site, and for the construction of nearly 20 miles of public and private roads, with the necessary culverts and bridges. Among the latter structures, a suitable highway suspension bridge at a narrow place near the middle of the reservoir, and the adaptation of the crest of the high masonry dam for roadway purposes, have been included.

Without reciting the numerous other items which enter into the design and cost of the dam and reservoir, it may suffice to state that the estimated cost of this part of the work is $4,985,000, to which 10 per cent. should be added for contingent expenses, thus making a total of $5,483,500. The prices adopted for the various items are believed to be ample, and if the asssumed land values are not greatly exceeded, the work can be completed within the said amount. It should, however,

be mentioned that no provision has been made for compensating owners of mill privileges on Indian Creek, in and below the reservoir site, as there are no mills in this portion of the valley which make use of water power.

Tunnel Conduit.

As the site of the proposed high dam is about 3.5 miles above the mouth of Indian Creek, and the lofty mountain range called Chestnut Ridge extends without interruption for the entire length of the valley to the Youghiogheny River, the outlet conduit from the storage reservoir must either make a long detour through the lower part of said valley, or must pass in tunnel through the mountain. From considerations of ultimate economy, the latter plan has been chosen, so that the first part of the conduit will be a tunnel 26,400 feet, or 5.00 miles, long, beginning at about elevation 1,310 feet above sea at the north end of the dam. The excavation through the rocky strata of the mountain is to be made about 11 feet in diameter, so as to admit of a strong brick lining to form a horseshoe-shaped conduit, 8.5 feet high and wide inside, with a grade of one in 2,500, and a maximum discharging capacity of about 150,000,000 gallons per day. This capacity corresponds to the ultimate average daily yield of 130,000,000 gallons computed above for the Indian Creek and Laurel Hill Creek basins combined, with an allowance of 15 per cent. increase over the average for seasonal variation in demand.

Little argument is needed to demonstrate the expediency of adopting at once the limiting dimensions for such a work, and of building it in such permanent manner as to avoid future enlargement and repairs. The principal item of its cost is the excavation of a passageway, or heading, large enough to allow the workmen to perform their task expeditiously, and after this has been done, the removal of the rest of the material is effected at relatively low rates. Between a suitable conduit of two-thirds of said capacity and the one here proposed, the difference in first cost will amount to only about $165,000, which sum is of slight significance in comparison with the large initial cost of nearly $1,000,000 for the smaller conduit. A subsequent enlargement of the conduit is manifestly impracticable, as the water supply to the city cannot be interrupted, and the construction of a parallel tunnel in the future will make the ultimate costs of the work excessive. It is therefore advisable to adhere to the size and capacity above indicated.

The tunnel conduit above described will terminate on the western side of the mountain, at about elevation 1,299 feet above sea level in the valley of White Run, where a suitable overflow chamber, or waste weir, will prevent the masonry lining from being subjected to any undue internal water pressure. Its construction is to be facilitated by several

deep shafts along its course, which will enable the work to be prosecuted simultaneously in both directions at a corresponding number of points, as well as from the ends, and which will afterwards be equipped with brick ventilating stacks, or manholes, 4 or 5 feet in diameter, the remainder of the shaft excavation being refilled with the material originally removed. The execution of the conduit work as thus planned will require about three years, while that of the reservoir and dam will require at least four years.

Steel Pipe Conduits.

From the end of the tunnel conduit, the ground descends rapidly to the general level of the tops of the lower ranges of hills between Chestnut Ridge and Pittsburgh, and its configuration is too irregular and unfavorable to admit of the construction of a continuous masonry aqueduct. A route might possibly be selected which would be characterized by a number of detached sections of such conduit, amounting in the aggregate to a length of several miles; but no effort was made in this direction, as the possibility of subsidences of the surface over the numerous coal mines which occur along any practicable route, renders the selection of such an aqueduct inexpedient. For this reason the use of riveted steel pipe alone has been considered for the remainder of the conduit.

So far as can now be determined from the best available data, the distance in a direct line from the end of the aforesaid tunnel to Highland Park Reservoir is about 199,000 feet, or 37.70 miles. Such a location for the conduit is, however, impracticable on account of its passage over numerous intervening summits and ridges, which are at so great elevations above the hydraulic grade line as to require the construction of expensive and undesirable tunnels, particularly in the mining districts. It has, therefore, been necessary to find another feasible location for the pipe conduit, and such a one is shown on the accompanying map.* Doubtless this route is susceptible of much improvement, but as it has not been deemed advisable to spend further time in making elaborate surveys, it is submitted merely as a rough possibility. Its length, following the undulations of the surface and with a liberal allowance for probable lateral detours, is 221,000 feet, or 41.86 miles, which is about 11 per cent. more than the air line distance mentioned above.

The elevation of the end of the tunnel was stated in the foregoing to be about 1,299 feet above sea level, and it should be remarked that this refers to the bottom of the 8.5 foot conduit. In considering the pipe line, however, the elevation of the water surface in said conduit, which is at least 6 feet higher, should be taken into account. At the

* See Plate No. 11, opposite Page 100.

beginning of the pipe the elevation of the hydraulic grade line will accordingly be at 1,305 feet above sea level, while at its end in Highland Park Reservoir its elevation will be 1,067 feet. The total available fall in the aforesaid distance of 221,000 feet is thus 238 feet, which gives a grade of one in 928.6 or 5.686 feet per mile; but in order to err on the safe side and to compensate for loss of head in entering the pipe, we may take for this grade, one in 935. For the required discharge let us adopt, as already set forth, 75,000,000 gallons per day, which is equivalent to 116.043 cubic feet per second. With these data, and taking for the coefficient (c) in the general Chezy formula ($v = c\sqrt{rs}$) for the mean velocity of discharge in a pipe an average value of c = 100, we will obtain:—

1. For a single line of pipe, required diameter = 73 inches.
2. " double " " " " " = 55 "

It must, however, be remembered that in the course of time the delivering capacity of all cast iron or steel conduits will be more or less impaired by an increasing roughness of surface, due to corrosion and the formation of organic growths on the interior; hence, while the assumed value of the coefficient (c) in the aforesaid formula is applicable to the average condition of the riveted steel pipe, it will be expedient to consider that its condition is inferior to the average, or such as may be expected to occur after it has been in use for 20 years. We should therefore add about 2 per cent. to the diameters as computed above, thus obtaining the values:—

1. For a single line of pipe, least required diameter = 74 inches.
2. " double " " " " " = 56 "

Where a pipe conduit of such great length is to be used for a public water supply, and is, moreover, laid in ground which is liable to be disturbed by subsidences over coal workings, it is advisable to have at least two lines of pipe available, as it may be presumed that both will not be out of order at the same time. This plan has been adopted in estimating the cost of the proposed gravity conduit, and the figures are accordingly based on the use of two lines of 56-inch riveted steel pipes for the entire distance from the end of the tunnel under Chestnut Ridge to Highland Park Reservoir.

After the aforesaid average daily supply of 65,000,000 gallons, corresponding to a maximum of 75,000,000 gallons per day during periods of greatest consumption, which is afforded by these two pipes, has become inadequate, a third similar line must be laid, whereby the combined capacity will be increased to a maximum of about 112,000,000 gallons per day, corresponding to a daily average of about 97,000,000 gallons, which is a little more than the safe capacity of the Indian Creek

water-shed, as already pointed out; and when this latter supply becomes insufficient, a fourth similar line must be provided, along with the tunnel from Indian Creek to Laurel Hill Creek, and the storage reservoir in the valley of the latter, as previously mentioned. The fourth pipe will thus make the combined conduit capacity about 145,000,000 gallons per day as a maximum, which corresponds to a daily average of about 130,000,000 gallons. This ultimate development practically exhausts the yield from these two mountain basins, and if still more water is required in the future, another source must be found.

Intermediate Structures on Pipe Conduits.

As the quick stoppage of the flow in any pipe conduit, such as is caused by the closing of a main valve, produces considerable increments of pressure, and hence also severe stresses in the metal, it is expedient to minimize these undesirable effects in the long line under consideration by dividing it into at least four sections each of about 10 miles in length, at the ends of which a free discharge for the water is provided by means of either a suitable basin, or an overflow similar to a waste weir on a canal. With the former, the advantage of saving the water for use is gained; but as there has been no time available for finding proper locations for such intermediate reservoirs of serviceable magnitude, and as their cost will add largely to the estimate, it has been deemed advisable to provide only for simple overflows or spillways at three or four convenient localities.

Brief reference may also be made to the special constructions needed where the pipes cross under or over large streams, under railways, and over coal workings. In all these cases, considerable expense is involved in rendering the pipes reasonably safe against future disturbance by floods, derailment or subsidence. Furthermore, the conduits should be coupled together with interposed stop-valves at frequent intervals in territory where danger from any of said causes may exist, so that in case of damage to one line, the flow of both pipes may be forced through a relatively short section of the other pipe at the expense of some loss of head, and then continue again in both pipes. Some reduction in the delivery will thus be incurred, but by no means as much as will happen if only one pipe remains in service for its entire length. The adoption of this scheme, however, leads to the use of a large number of main stop-valves.

In addition to the foregoing items, a large number of air-valves at summits and blow-offs in depressions of the pipe lines, will be required, as well as a telephone line and various roadways for facilitating the construction and subsequent operation of the conduit. The different sections must, moreover, be kept under constant supervision, as small leaks under high pressure may quickly enlarge and lead to great damage;

hence several dwellings, tool sheds, etc., for the conduit overseers, as well as for the keepers of the storage reservoir, must likewise be provided.

Reference might also have been made to a great variety of other details connected with the pipe conduit, such as manholes to afford access to its interior, anchorages at its ends and intermediate points, masonry for carrying minor natural water-courses under or over the conduit, the various easements and mining rights needed for the construction and future protection of the work, etc.; but as this report has already greatly exceeded the limits originally designed therefor, all these other matters are accordingly omitted. It may, however, be of interest to remark that in the hands of an energetic and experienced contractor, the pipe conduit can readily be completed within a period of three years.

Estimated Cost.

The detailed estimate of the cost of the entire gravity system of water supply from Indian Creek may now be conveniently grouped into the following general items:—

1.	Masonry dam and appurtenances	$ 3,673,000
2.	Clearing reservoir site of timber, brush, earth, and vegetable mould, along with sanitary work beyond limits of territory acquired	730,000
3.	Construction of necessary public and semi-public roads, culverts, bridges, fences, railings, etc., together with purchase of land for site, and compensation for buildings removed	582,000
4.	Tunnel conduit, 8.5 ft. diameter, and 26,400 ft. long, with necessary shafts and ventilating manholes, complete	1,167,200
5.	Two lines of 56-inch riveted steel conduit pipe, each 221,000 ft. long, with the necessary valves, overflows, creek and railway crossings, masonry and other appurtenances, complete	5,583,450
6.	Rights of way for tunnel, shafts and pipe conduit with appurtenances, purchase of coal mining rights, supporting roofs of exhausted mines to prevent subsidence, clearing land and grading roadways for construction on rights of way, dwellings, etc., for reservoir and conduit overseers, telephone line, and expenses not otherwise enumerated	599,350
	Sum of foregoing items	$12,335,000
7.	Add 10 per cent. for engineering, inspection, legal expenses and contingencies not now foreseen	1,233,500
	Total estimated cost of work for a maximum capacity of 75,000,000 gallons per day for the pipe conduit	$13,568,500

As already stated, when the average daily water consumption in the city exceeds 65,000,000 gallons, which corresponds to the maximum delivery of 75,000,000 gallons per day mentioned in the above estimate, it will be necessary to lay a third line of pipe. The cost of this line will probably be somewhat less than one-half of the above-named item for pipe conduits, since its construction will be greatly facilitated by the original work, and but little expense is involved for connecting with the various overflow channels and inlet chamber at the distributing reservoir. An approximate estimate of the cost of said third line is $2,774,775, to which 10 per cent. should be added for contingencies, etc., as above, thus making a total additional cost of $3,052,250, in order to adapt the delivering capacity of the pipe conduits to an average daily consumption of about 97,000,000 gallons, with a maximum of 112,000,000 gallons per day.

In like manner, when this latter quantity becomes inadequate, the development of a supplementary supply from the Laurel Hill Creek basin must be carried out, at an expense of about $3,000,000, as already indicated, and a fourth line of pipe must also be provided at the aforesaid sum of $3,052,250, whereby the total cost of this final increment becomes $6,052,250. The works will then be adapted to the ultimate average daily supply of about 130,000,000 gallons, with a maximum of 145,000,000 gallons per day; and their probable total cost will have been as follows:—

For original cost with two lines of pipe and average daily consumption of 65,000,000 gallons	$13,568,500
For addition of third line of pipe	3,052,250
For addition of fourth line of pipe and Laurel Hill Creek basin	6,052,250
Ultimate cost	$22,673,000

Operating Expenses and Maintenance.

The annual operating expenses of the gravity system of water supply outlined in the foregoing are quite small in comparison with those of a pumping and filter system. A force of six intelligent men with a few helpers, and the occasional employment of other manual and team labor, will suffice to keep the conduits, storage reservoir, buildings, accessory roadways, bridges and culverts, and the telephone line in good order, at an estimated expense of about $14,000 per year, on the average; but it should be distinctly understood that this sum does not include any allowance for extraordinary repairs or renewals. To meet the latter expenditures, drafts may properly be made upon the accumulation of money in the sinking fund, which may be established for the payment of the bonded debt incurred for constructing the works.

In fixing the term of years for the maturity of such a sinking fund, it will be proper to discriminate between those portions of the works which are of permanent value and indefinitely long durability, such as lands, easements, mining rights, the great masonry dam and its appurtenances, the tunnel conduit, overflow-channels, roadways, etc., and the remaining portions which are subject to deterioration or decay, such as the riveted steel conduits, with their various valves and appurtenances, the iron or timber roadway bridges, minor masonry objects, wooden buildings for overseers, telephone line, etc. For the first-named class, it may justly be urged that the sinking fund term should not be less than 100 years; but as it is generally considered expedient to maintain the credit of a large municipality at a high standard, in order that it may be enabled to borrow money at low rates in case of emergency, a period of 60 years has often been adopted as a limit. For the second class of structures, on the other hand, it is fair to assume an average life of about 40 years, and hence this term may be taken for the sinking fund for the corresponding part of the original bonded debt.

For the first outlay of $13,568,500 mentioned above, the cost or value of the permanent portions of the work is estimated at $7,379,020, while that of the remaining portions is $6,189,480. Assuming sinking fund terms of 60 and 40 years respectively, for these two sums, and considering that interest at the rate of 3 per cent., compounded annually, will be paid for the use of the money accumulating in these funds, then the annual contributions from the city to said funds must be 0.6133 and 1.3262 per cent. of the respective sums or principals. The annual payment into the former fund will accordingly be $45,255.53, while that for the latter is $82,084.88, thus making a total yearly sinking fund payment of $127,340.41.

With reference to the annual interest on the bonded debt, a rate of 3.25 per cent. has been adopted, at the suggestion of some members of the Commission; and by arranging the preceding items in tabular form, we now obtain the following statements of the fixed annual charges and operating expenses of the proposed gravity system:—

I. For the period of years until the average consumption exceeds 65,000,000 gallons per day, with a maximum of 75,000,000 gallons per day for short times:—

Interest at 3.25 per cent. on total estimated cost of works, $13,568,500	$440,976.25
Sinking Fund payment, as above	127,340.41
Ordinary operating expenses for salaries, wages, and minor repairs	14,183.34
Total yearly charges	$582,500.00

II. For the next period of years, after the addition of the third line of pipe, at a cost of $3,052,250, and until the average consumption exceeds 92,000,000 gallons per day, with a maximum of 112,000,000 gallons per day for short times:—

Yearly charges for first period, as above	$582,500.00
Interest at 3.25 per cent. on cost of third line of pipe, $3,052,250	99,198.13
Sinking Fund payment for term of 40 years, being 1.3262 per cent. of said cost of third pipe	40,478.94
Addition to operating expenses, to round up	122.93
Total yearly charges	$722,300.00

III. For the next period of years, after the addition of the fourth line of pipe and the Laurel Hill Creek basin, at a combined cost of $6,052,250, and until the average consumption exceeds 130,000,000 gallons per day, with a maximum of 145,000,000 gallons per day, for short times:—

Yearly charges for second period, as above	$722,300.00
Interest at 3.25 per cent. on cost of fourth line of pipe and Laurel Hill Creek basin work, $6,052,250	196,698.13
Sinking Fund payment for term of 40 years on cost of pipe, being 1.3262 per cent. of $3,052,250	40,478.94
Sinking Fund payment for term of 60 years on cost of Laurel Hill Creek basin work, being 0.6133 per cent. of $3,000,000	18,399.00
Addition to operating expenses, to round up	123.93
Total yearly charges	$978,000.00

Conclusion.

It will be noticed that in the foregoing I have confined myself to a brief technical description of the proposed gravity conduit, and have therefore left the comparison of this plan with other projects for improving the water supply of Pittsburgh to be drawn by the Commission and yourself. With reference to the feasibility of the plan, it may be remarked that the only element of engineering uncertainty attached thereto is the question of damage from possible subsidence of the ground over coal workings. The estimate, however, contains a fair allowance for the acquisition of ample mining rights, and presumably the state laws are adequate to protect the property thus acquired against en-

croachment or removal. From a financial point of view, on the other hand, there is little to say until the estimates for the other projects have been presented on the same basis as indicated above.

Respectfully submitted,

E. KUICHLING,

Civil Engineer.

Rochester, N. Y., December 27, 1898.

REPORT

OF THE

Resident Engineer,

MORRIS KNOWLES, C. E.

EXHIBIT 4.

MR. ALLEN HAZEN,

Consulting Engineer,

Pittsburgh Filtration Commission.

SIR:—

I beg to submit, herewith, the report upon that portion of the work of the Filtration Commission which has been under my direct charge, since May 17, 1897, when I reported for duty.

The experiments, for which arrangements were early made, and which were started as promptly as possible, were officially closed September 1, 1898. Since then, the time has been largely occupied in compiling data, and in preparing the reports; however, some little additional experimental work and investigations have claimed a portion of this latter period.

CHAPTER I.

GENERAL OUTLINE OF THE WORK.

Organization.

Through the courtesy of Mr. E. M. Bigelow, Director of Public Works, and Member of the Filtration Commission, a room was assigned, May 19, 1897, for the use of the Commission, on the third floor of the City Hall, and this continued to be used as the office until November 14, 1898. At this date, because of the need of more room, for the increased force, required for the early preparation of the report; also, to secure better light for the draftsmen, we moved to the fifth floor. But, a few days later, on November 19, the Herron Hill Laboratory Building was assigned for the remainder of the work.

Among the items of work first undertaken was that of making chemical analyses of different samples of water and the services of the chemist, Dr. Walther Riddle, date from May 17, 1897. By the kindness of Messrs. Coster and Riddle, this work has been done in their private laboratory, and for this we are under many obligations to the firm; also, especially to Mr. Coster, in assisting at times when the work was particularly urgent. We began at once to collect samples for chemical analysis, from the Allegheny and Monongahela Rivers, and from representative taps in the cities of Pittsburgh and Allegheny. Samples were collected from a well which was drilled at that time adjacent to the boiler house at Brilliant. A discussion of these analyses will be found in the Chemist's Report, Appendix No. 1, and the results in Appendix No. 2. The special report upon this driven well, made by Mr. A. B. Shepherd, Superintendent of Bureau of Water Supply and Distribution, to the Director of Public

Works, will be found in Appendix No. 5. Considerable time was also occupied during the first few weeks in securing the necessary apparatus and utensils for the laboratory, and, in addition to his regular duties, the Chemist assisted the Resident Engineer in organizing the work.

Sometime prior to the organization of the work upon the present basis, the Commission had arranged with Dr. Eugene Wasdin, Past Assistant Surgeon, United States Marine Hospital Service, to analyze representative samples of the Pittsburgh water supply and report upon the species of bacteria found therein. Dr. Wasdin's Report will be found in Appendix No. 3. His work was conducted in the laboratory of the Bureau of Health, Department of Public Safety. For this kindness, as well as for the many favors obtained later, until our own laboratory at Brilliant was completed, we are deeply indebted to this department and its officials, and it is desired at this time to express our thoughtful appreciation of this assistance.

As it was not possible to secure the whole of Dr. Wasdin's time for the work of the Commission, other arrangements were ultimately made, and, upon July 1, 1897, Mr. Wm. R. Copeland, Assistant Biologist at the State Board of Health Experiment Station, Lawrence, Mass., reported in Pittsburgh to assume charge of this branch of the work. In the beginning, the work consisted in analyzing samples of river and tap waters, in preparing sketches for fitting up the laboratory at Brilliant and in securing apparatus for the same. When the sand filters were started, July 23, 1897, the number of bacterial analyses was largely increased. The new laboratory at Brilliant was used after August 23, 1897, where the work has since been performed. The Bacteriologist has not only performed the necessary laboratory work, but has had direct charge of the experimental filter plant.

Sand Filters.

Acting upon the decision made at a meeting, held May 19, 1897, steps were immediately taken to construct, for experimental purposes, two sand filters at Brilliant with a settling basin. A description of these filters and a statement of the operations and the results obtained therewith, will be found in Chapter II.

Mechanical Filters.

Preliminary steps were taken, upon May 22, 1897, to see what arrangements could be made to experiment with representative types of mechanical filters. Invitations to install their filters for experimental purposes, upon the basis of all expenses to be borne by the companies, were sent June 5, 1897, to the following filter companies:—

Cumberland Manufacturing Company, Boston, Mass.
Morrison-Jewell Filtration Company, New York, N. Y.
New York Filter Manufacturing Company, New York, N. Y.
Continental Filter Company, New York, N. Y.
Loomis-Manning Filter Company, Philadelphia, Pa.

All of these companies declined, either at this time or later, to enter the test as originally proposed. After many conferences, agreements were drawn up, upon August 24, 1897, with the Cumberland Manufacturing Company and the Morrison-Jewell Filtration Company, for establishing their filters for experimental purposes. These agreements provided that each company should furnish, free on board cars at point of manufacture, a complete filter with alum apparatus, and other necessary accessories; also, furnish a competent superintendent to supervise the erection of the same, and should loan the filter to the city of Pittsburgh, without recompense, for a period not later than to January 1, 1899. It was also agreed that the city should pay all freight charges to Pittsburgh; also, should furnish all labor and material necessary for the erection and the necessary shelter, labor, power, alum, and water for operating the filters. It was furthermore provided, that, at the conclusion of the experiments, the city should take down, pack, and deliver free on board the cars at Pittsburgh, all parts of the filter. It was also agreed that each company should be informed from time to time as to the bacteriological, chemical, and mechanical results secured with its own filter, but these results were to be regarded as confidential until the final report had been made to Councils. These agreements were approved by Councils, and signed by the Mayor, October 13, 1897.

Considerable time was thus occupied during the negotiations, and, again, after the agreements were signed, before the filters were actually received upon the ground. The apparatus first began to arrive November 4, 1897, but it was January 14, 1898, before the filters were in operation. During the first few months of the experiments with the mechanical filters, representatives of the filter companies were in attendance, to advise in regard to the operation of their respective filters.

Upon April 7, 1898, notice was received that the Cumberland Manufacturing Company and the Morrison-Jewell Filtration Company had sold to the New York Filter Manufacturing Company, all patents and rights of their respective filters. A description of the Warren Filter, with the results of the experiments, will be found in Chapter III; and of the Jewell Filter, in Chapter IV.

Worms Tile Filter.

At Worms, Germany, filters are used which are composed of plates of artificial sandstone. Some of these plates had been secured by Hon.

Wm. Flinn, Member of the Commission, and tried by him in an experimental way. Through his kindness, negotiations were made with the American representative of Director Fisher of Worms, the inventor of the system, and six tiles were secured and set up at the experimental filter plant, according to the plans and directions furnished. They were placed in operation November 25, 1897, and continued until April 9, 1898. During this time, the American rights had been transferred to the Wormser Filter Plate Company, of St. Louis; and they, in a communication dated March 29, 1898, asked permission to re-establish the plant and have the experiment continued. This was granted by the Commission, and, upon June 12, 1898, the test began again, under the general supervision of a representative of the Wormser Filter Plate Company, and continued until the close of the experiments. A description of this filter plant, and the results obtained therewith, will be found in Chapter V.

Berkefeld Filter.

Upon November 12, 1897, a proposition was submitted by the Berkefeld Filter Company, requesting the Commission to consider the practicability of placing household filters of their type, in all buildings throughout the city of Pittsburgh. The estimate of the company for installing 56,000 Berkefeld Home Filters, according to their system, was $560,000, and the annual operating expenses, exclusive of interest, was $189,000. The question was taken under consideration and a household filter of the Berkefeld type was submitted to us for the purpose of testing its efficiency. It may be stated that, in general, a large number of the bacteria in the water were removed, when the filter was carefully attended to. Frequent washings were necessary and occasionally the filter cylinder had to be sterilized by boiling.

Surveys.

It was thought advisable to have a survey made of certain flatlands, along the north side of the Allegheny River, which might afford suitable sites for filters. This work was done, under the general supervision of the Resident Engineer, by a party of five men from the City Engineer's office, under the direction of Mr. W. W. Fortune. They were employed upon this work as time could be spared from other duties and we are indebted to the Director of Public Works, and to Mr. Wm. R. Brown, City Engineer, in regard to this. This survey was begun August 17, 1897. The field work was finished October 27, 1897, and the plans were completed February 19, 1898. The survey included about 600 acres, which extend about three miles along the Allegheny River, from the easterly line of Aspinwall to Montrose Pumping Station.

Later, it was decided to secure information in regard to the topographical character of the land along Squaw Run, which stream enters the

Allegheny River, a short distance above Aspinwall, and cuts through the foot-hills, bordering on the flat-lands, on the north side of the river. It was thought that the basin of this run might afford a good site for a large storage or settling basin for filters, located on the flat-land below. As the force of the City Engineer was busy at that time, a contract was made with Messrs. Wilkins and Davison, Civil Engineers, of Pittsburgh, to furnish the data and plans of this survey. The field work was begun May 9, 1898, and ended May 25, 1898, and the completed plans were delivered June 8, 1898. The survey comprised about 200 acres which extend up Squaw Run for a distance of about two miles from the foot-hills. Maps prepared for these surveys have been transmitted to you as completed.

Gravity Supply.

Upon May 26, 1898, a communication was received from the Western Water Company, requesting the Commission to consider whether it would be advisable for the city of Pittsburgh to secure a gravity water supply from a mountain water-shed in Fayette County, Pa. The company has certain rights in this territory and furnished the Commission with much detailed information and plans which had been made. It was deemed expedient, however, to secure additional data and a knowledge of the character of the material to be encountered in constructing the proposed dam and conduit. The additional surveys were made by Messrs. Jamison and Fogg, Civil Engineers, of Greensburg, Pa., acting for the Western Water Company. Information in regard to the drainage area and particulars in regard to the character of the geological formation along the conduit line, and the liability of having "sinks" in coal territory, were secured by the engineering force of the Commission.

Miscellaneous Studies.

Studies have been made of the past and present population in Pittsburgh and of the probable future increase; similar studies have also been made in regard to the consumption of water. Investigations have also been made for a projected auxiliary supply of water for manufacturing purposes, which involved securing data of the manufacturing use of water and a study of the location of main pipes for this system. All of which information has been transmitted to you from time to time.

During the summer and autumn of 1897, several epidemics of typhoid fever occurred in the vicinity of Pittsburgh and one within the city limits. Considerable attention and study were devoted to these for the purpose of investigating the cause of the excessive amount of this disease in the city. It was found that typhoid fever is generally existent here and in the suburban villages and boroughs; and the results of our investigations

indicated that epidemics are frequently to be traced to the use of infected milk, and also, to the use of contaminated well and spring waters.

Besides the investigations above mentioned, information and data were obtained for Prof. W. T. Sedgwick, who was retained by the Commission to report upon "The Sources of Typhoid Fever in Pittsburgh." A diagram was made, showing the location of the cases of typhoid fever, reported in the city, in 1897. Other statistical information was also secured; all of which will be found in Prof. Sedgwick's Report.

Pollution Investigations.

Prior to the engagement of the Resident Engineer, investigations were undertaken, under the general direction of Dr. W. J. Holland, Chairman of "Committee of Water Analysis," to ascertain the extent and character of the pollution of the Allegheny and Monongahela Rivers and their main tributaries. Eight young men, students of the Western University of Pennsylvania, were employed, upon this investigation, during the Holiday vacation of 1896. They studied the sanitary condition of the banks of the streams and the amount of pollution entering therein. The results are such that they cannot readily be placed in convenient form for publication, but they show that a large amount of sewage is being thrown into these streams from towns, villages, manufactories, and dwellings all along their courses, even in the upper waters.

Experimental Filter Plant.

A brief description of the experimental filter plant is given herewith, and the exact details will be included in the reports of each of the several systems. The plant consisted of two sand filter basins, together with a settling basin, built of concrete; located between the Allegheny Valley Railway tracks and the Allegheny River, about two hundred feet from the westerly end of No. 4 Boiler House, at Brilliant Pumping Station. Just west of the sand filter basin was located the filter building; in size thirty-four feet wide, by sixty-two feet long. Attached to the westerly end of this building, was the shed in which the experimental boilers were placed. The biological laboratory was located close by the sand filter basin, at the westerly end of a wooden building, which was used as a store-room and carpenter shop. Plate No. 12;—"General Plan of Experimental Filter Plant," opposite this page, shows the relation of these structures.

Water was supplied by a six-inch cast iron pipe, leading from the force main in the pumping station yard. This pipe was about 240 feet long, and lead directly to the inlet chamber of the sand filter plant. A six-inch branch, about 75 feet long, led from the first line to the filter

building. Steam was applied for uses in the filter building through a six-inch line, about 330 feet long, leading from the No. 4. Boiler House. A tap from this line furnished steam for heating the laboratory and supplying the autoclave. The water was distributed to the respective filters by a suitable arrangement of the piping. The pressure of the supplied water was about 150 pounds, which was too much for the butterfly valves on the inlets to the mechanical filters to control. It was necessary, therefore, to place a regulator on the main line in the building, which device reduced the pressure to about forty or fifty pounds. The effluents from the sand filters passed through three-inch pipes to a measuring vault located within the filter building, and thence out through a drain into the river. On its way, the water was caught in a barrel which allowed us to secure, with a small pump, filtered water for the purpose of supplying the laboratory, filling the sand filters after scraping, and such other uses as were found desirable. The effluents from the filters in the building were delivered into a large iron tank under the floor. This tank was sixteen feet in diameter, ten feet high, and was placed in the ground before the building was erected. Water was obtained from this tank for washing purposes, and delivered by two pumps, through suitable piping, to the filters. The wash water and waste from the several filters ran into the river through a drain underneath the building.*

Boiler Experiments.

As large quantities of water are used in Pittsburgh for manufacturing purposes, in boilers and in various hydraulic devices, where it is stored in metal tanks, it was thought advisable to investigate the corrosive and incrusting qualities of the Allegheny River water before and after filtration. For this purpose, three 25 H. P. boilers were kindly loaned to the Commission by the Oil Well Supply Company, and to this company we are deeply indebted for this favor, and for kind attention and advice in carrying out these experiments. A complete report of these tests will be found in Chapter VI.

Asbestos.

After the conclusion of the experiments by the Commission, it was brought to our attention that it was possible to use asbestos as a layer upon filters, and it was decided that certain tests should be undertaken with this material as a filter medium. As the time for this was limited, however, and the experiment somewhat incomplete, no statement of the results is given in this report.

General.

Frequent visits have been made to the experimental filter plant by interested citizens, also by residents of other places. The Commission made,

*Arrangement of apparatus in filter building is shown upon Plate No. 13, opposite Page 116.

in addition to those by individual members, four official visits, viz.:—June 26 and July 23, 1897: June 18 and August 24, 1898. Upon the latter occasion, which was shortly before closing the experiments, Members of Councils and interested citizens were invited. Occasional visits were also made by the officials of the different filter companies, whose apparatus was being tested.

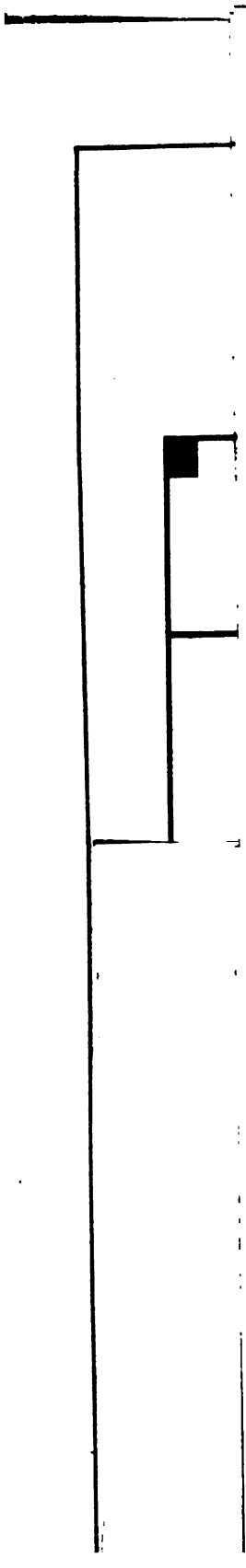
The Resident Engineer has visited, at the request of the Commission, various filtration plants and investigated several devices not experimented with here. He also accompanied the chairman and a Committee, on an inspection of the experimental filter plants at Louisville, Ky., and Cincinnati, Ohio, made April 19, and 20, 1898.

During the investigations, it has been necessary to make frequent observations daily of the various gages located at the experimental filter plant. Observations of the turbidity of the river water, settled water, and effluents, were made daily. Frequent samples were collected during the day for bacterial determinations and, twice a week or more frequently, samples were collected for chemical analysis. All of this data has been reported from time to time, and weekly reports upon the progress of the work and results have been submitted to the Commission. Also reports of each week's results of the operations of the mechanical and Worms Tile Filters have been sent periodically to the respective filter companies.

In carrying on this work the writer has, on many occasions, received kindly aid and support from the officials of the various city departments, from the authorities of the United States Weather Bureau and Engineer's Office, and many other citizens. To Mr. A. B. Shepherd, Superintendent of Bureau of Water Supply and Distribution, the writer is especially indebted for advice and valuable assistance. We are also indebted to the officials of the various railroads, and especially to those of the Allegheny Valley Railway and Pennsylvania System, for courtesies in regard to facilities and arrangements for transportation and prompt delivery of all material needed in our experimental work. To all these gentlemen the writer wishes to express his thankful appreciation for their kindness.

There have been employed, under the direction of the Resident Engineer, during the experiments, the following persons in the respective positions indicated, and, for their thoughtful appreciation and thorough attention to the work, the writer is deeply indebted:—

Dr. Walther Riddle,	Chemist.
Wm. R. Copeland,	Bacteriologist.
Frank B. Smith,	Laboratory Assistant.
Geo. W. Biggs, Jr.,	Engineering Assistant.
Wm. Toy,	Filter Attendant.



Andrew Mount,	Assistant Filter Attendant.
Patrick Ging,	" " "
Wm. Birchell,	" " "
Robt. C. Johnston,	Observer.
Fred. W. Henrici,	"

At different times, others have assisted in various capacities; also, mechanics and laborers have been employed during the construction of the plant and in dismantling the same. During the preparation of the report the force was largely increased for about six weeks, a maximum of twelve persons being employed for this purpose.

The subjects in the Resident Engineer's Report have been considered in the following order:—

Chapter I—General Outline of the Work.
Chapter II—Sand Filter Experiments.
Chapter III—Warren Filter Experiments.
Chapter IV—Jewell Filter Experiments.
Chapter V—Worms Tile Filter Experiments.
Chapter VI—Boiler Experiments.

Appendix No. 1—Chemist's Report, by Dr. Walther Riddle.
Appendix No. 2—Tables of Chemical Analyses and Descriptions of Sources of Samples.
Appendix No. 3—Bacteriologist's Report, by Dr. Eugene Wasdin.
Appendix No. 4—Bacteriologist's Report, by Mr. Wm. R. Copeland.
Appendix No. 5—Report upon Driven Well Supply, by Mr. A. B. Shepherd.
Appendix No. 6—Financial Statement.

CHAPTER II.

SAND FILTER EXPERIMENTS.

Description.

A plan and section of the sand filter plant is shown upon Plate No. 14, opposite page 118. The entire structure was made of concrete. The water was supplied through a six-inch pipe to the gate chamber, at the easterly end of the settling basin. Water from this chamber flowed, as desired, either into the settling basin or into either of the filters. There were also pipes which led from the settling basin into the filters. It was possible by this arrangement to supply either of the two filters with raw water or settled water. The settling basin held about 33,800 gallons, which allowed twenty-four hours sedimentation for the water passing through, when one filter alone was supplied with settled water, and at

a five million rate. Suitable overflows, one at the gate chamber and one in the settling basin, provided that the head of the water upon the filters could be maintained at a constant elevation.

The filter basins are about 25.2 feet by 12.7 feet, at the top of the walls. The exact area of the sand surface of No. 1, at the beginning, was 285 square feet, and of No. 2, was 291 square feet; upon September 1, 1898, these figures were 273 and 279 respectively, owing to the lower level of the sand and the batter of the walls. The underdrains were of vitrified pipe, with broken stone and gravel placed about and above them, all of the ordinary construction and as shown upon the drawings. Most of the sand used was dredged from the Allegheny River, also a portion from the Ohio River, a short distance below the Point. A statement of the mechanical and chemical analyses is given upon page 121. The sand was deposited in six layers, each being carefully smoothed and leveled. The basins were then filled with water and after the sand had been in place for a few days, the depth was only 4.2 feet. Considerable sand was removed during the operations, by scraping, and there were only 3.1 feet left in Filter No. 1, and 2.9 feet in Filter No. 2, after scraping, just before September 1, 1898.

The effluent pipes of the filters were brought side by side into a small chamber located in the filter building. In this chamber were placed the necessary gates, meters, indicators, and gages for regulating and registering the quantity and determining the loss of head. There were also quarter-inch taps upon the pipes, from which chemical and biological samples were obtained. Meters were placed upon these pipes, after which the water passed through standard orifices. As air interfered with the action of the meters, the orifices were found more reliable and results from them, only, are used in making up the records.

The orifices were in the botton of copper cans which were 12 inches in diameter and 12 inches high. The bottoms were made of brass plates one-eighth inch thick. On the side of the can there was an opening, with a two-inch pipe connection soldered on, for the entrance of the water. In front of the opening there was a screen with perforations, so that the velocity of the water was lessened and a direct downward current prevented. Ten standard orifices were drilled in the bottom plate, each of an average diameter of 0.503 inch. These orifices discharged into a trough below, which emptied into a pipe, delivering out under the building. On one side of the indicator there was a glass slide upon which a scale was fastened. This scale was graduated to read, upon one edge, in "Gallons per Orifice Daily," and upon the other, in "Million Gallons per Orifice per Acre Daily." In this way it was possible to determine, at one reading, both the actual quantity in twenty-four hours and the rate of filtration.

OPERATIONS.

The gates were changed to regulate the flow at 9.00 A. M., and, if ncessary, when the loss of head was great, again at 9.00 P. M. The attendants were instructed to keep the depth of water upon the orifices at the half million rate mark, so that one-half the number of orifices open, corresponded to the approximate rate of filtration. Orifices not in use were closed by rubber stoppers. Readings were taken at 9.00 A. M. 3.00 P. M., 9.00 P. M., and 3.00 P. M. Additional readings of the indicators were taken when a filter was being drained, preparatory to scraping, and when first starting in operation again. The observation of the loss of head was also made at 12.00 M., which record is used in the tables.

Water was first introduced into the settling basin July 15, 1897, and, upon July 17, it was allowed to pass slowly into the filters, in order to saturate the sand. Upon July 24, 1897, the effluent valves were first opened, and, except for the interruptions for scraping and a few delays which will be noted later, this plant has continued in operation during the twenty-four hours of every day until the close of the experiments.

Periods of Operation,—Filter No. 1.

Filter No. 1 was at first operated at an approximate rate of 2,000,000 gallons per acre daily. On August 15, 1897, the rate was changed to 3,000,000 gallons, which was maintained throughout the experiments. It was always operated with settled water except on the following occasions, when water direct from the gate chamber was used, viz.:—

From	9.15	A. M.,	January	23,	to	8.58	A. M.,	January 26,	1898.
"	2.45	P. M.,	March	10,	to	12.00	M.,	March 12,	"
"	11.45	A. M.,	"	25,	to	3.45	A. M.,	" 26,	"
"	7.30	P. M.,	April	5,	to	4.18	"	April 6,	"
"	4.10	"	May	11,	to	6.02	P. M.,	May 14,	"
"	10.30	A. M.,	"	18,	to	12.10	"	" 19,	"
"	7.30	P. M.,	June	16,	to	12.30	"	June 19,	"
"	10.30	A. M.,	July	17,	to	9.26	A. M.,	July 20,	"
"	11.06	"	"	25,	to	1.08	P. M.,	" 25,	"

Periods of Operation,—Filter No. 2.

Filter No. 2 was at first operated at an approximate rate of 2,000,000 gallons per acre daily.

At	9.20	P. M.,	August	15,	1897,	it was changed to a		3,000,000	rate.
"	9.05	A. M.,	December	19,	"	"	"	2,000,000	"
"	9.14	"	February	20,	1898,	"	"	3,000,000	"
"	9.00	"	June	30,	"	"	"	5,000,000	"

Filter No. 2 was at first operated with water direct from the gate chamber, except that, when running the second time at a 2,000,000 rate

and at a 5,000,000 rate, settled water was used. During the periods while running at these two rates, there were the additional exceptions, when water direct from the gate chamber was used, viz.:—

From	9.15	A. M.,	January	23,	to	8.58	A. M.,	January	26,	1898.
"	10 30	"	July	17,	to	9.28	"	July	20,	"
"	11.04	"	"	25,	to	1.08	P. M.,	"	25,	"

Cracks in Filter Walls.

High numbers of bacteria were noticed in the effluents, in November, 1897. Upon Saturday, November 13, 1897, Filter No. 2 was shut off to scrape, but the water did not run away as fast as usual. Upon looking for the reason, we found, in the dividing wall between the settling basin and the filter, a small crack close to the central well; this crack allowed the water from the settling basin to flow quite freely into the filter. The high bacterial numbers were probably caused by the water from the crack following down the concrete wall, which does not batter at this point, and thus into the underdrains without passing through sand. Upon emptying the settling basin, a similar crack was found at the corner of Filter No. 1. Both filters were immediately drawn off and the cracks were repaired by cutting out dovetail grooves and filling with cement mortar.

Both filters were scraped at this time and were put into operation again at 12.22 P. M. November 17, 1897. The surface of the filters, and the sand to some depth, at the point of repairs, became disturbed during this work; the sand surfaces also became slightly frozen. It is believed that these causes contributed to the large numbers of bacteria found in the effluents, for a few days afterward, and, to a lesser degree, throughout the cold season. It is believed, however, that the repairs were effectual; for, upon drawing down the settling basin upon December 7, 1897, with water still on the surface of the filters, no leaks were noticed.

During the latter part of May and the early part of June, 1898, the numbers of bacteria in the effluent, from Filter No. 1 were again high, and, when drawing down to scrape, upon July 15, 1898, a small leak was noticed at the place of the previous trouble. This time no attempt was made to stop the leak, but a small cement trough was built, out under the leak and over the sand; so that the water, instead of passing down between the wall and sand, was obliged to go out into the sand and be filtered. After this, no further trouble was noticed.

Methods.

After the middle of December, 1897, it became our custom to scrape as soon as the loss of head became four feet. Before each scraping the levels were taken at eighteen points over the surface, and again after

scraping, before the surface was raked. The average of the differences gave the depth removed. On February 17, 1898, we began the custom of tamping the sand gently after scraping, for a width of about two inches from the walls, in order to compact it and prevent water finding its way down by channels between the wall and sand. On and after November 23, 1897, the filters were filled with filtered water from below after each scraping.

ANALYSES OF SAND.

The following tables contain the results of the analyses of all the samples of sands which were collected. Some were of sand dredged from various places in the vicinity of Pittsburgh, and others of that used in the sand filters.

TABLE A.

Mechanical Analyses of River Sand.

No.	Calendar Date of Collection.	Place of Collection.	Effective Size, M. M.	Uniformity Coefficient.	Remarks.
386	June 3, 1897,	Allegheny River	0.32	2.1	Dredged near 43d Street.
389	" 15, "	" "	0.33	1.9	
387	" 24, "	Pile at Brilliant	0.27	2.6	Used in filters.
388	" 24, "	" " "	0.27	2.7	" " "
475	August 3, 1898,	Allegheny River	0.26	1.6	Dredged near Tarentum.
476	" 3, "	" "	0.19	1.8	" " "
477	July 26, "	" "	0.28	2.1	" " 43d Street.
478	" 26, "	" "	0.27	1.9	" " " "
479	" 26, "	" "	0.27	2.1	" " 16th "
480	" 26, "	Ohio River	0.33	1.8	" " Point.

TABLE B.

Chemical Analyses of River Sand.

No.	Calendar Date of Collection.	Place of Collection.	PARTS BY WEIGHT. Iron and Aluminum Oxides.	Calcium Carbonate.	Silicates and Insoluble Matter.
386	June 3, 1897,	Allegheny River	2.25	0.91	96.84
387	" 24, "	Pile at Brilliant	4.92	0.47	94.61
388	" 24, "	" " "	3.89	0.53	95.49
475	August 3, 1898,	Allegheny River	0.73	0.59	98.68
476	" 3, "	" "	0.97	0.36	98.67
477	July 26, "	" "	1.04	0.46	98 50
478	" 26, "	" "	0.54	0.31	99.15
479	" 26, "	" "	1.07	0.76	98.17
480	" 26, "	Ohio River	1.32	0.71	97.97

TABLE C.

Chemical Analyses of Sand Used in the Sand Filters.
Samples Collected,—July 13, 14 and 15, 1897.

Source of Sample.	Effective Size, M. M.	Uniformity Coefficient.
Filter No. 1	0.30	2.0
Filter No. 2	0.31	2.0

NOTE:—The above results represent the averages of analyses of the samples collected from each filter. A sample was collected from the up-stream and from the down-stream end of each of six layers as the sand was placed in position.

TABLE D.

Chemical Analyses of Sand Used in the Sand Filters.

Source of Sample.	PARTS BY WEIGHT. Iron and Aluminum Oxides.	Calcium Carbonate.	Silicates and Insoluble Matter.
Filter No. 1	0.98	1.32	97.70
Filter No. 2	0.96	1.35	97.69

NOTE:—An average sample of the sand in each filter was made by taking a portion of each sample collected.

TABLE E.

Condition of the Sand at Various Depths in the Sand Filters, After a Use of Fourteen Months.

Samples from No. 1, Collected September 16, 1898.
" " " 2, " " 14, "

Depth below the Surface.	Percentage of Calcium Carbonate by Weight.		Bacteria Per Gram.		Ammonia in Parts Per 100,000.	
	No. 1.	No. 2.	No. 1.	No. 2.	Albuminoid. No. 1.	Free. No. 1.
½ inch	0.39	0.57	2,440,000	1,720,000	11.00	3.50
1 "	0.21	0.43	340,000	1,080,000	6.00	2.50
2 "	0.45	0.39	230,000	250,000	3.00	3.25
3 "	0.30	0.36	100,000	190,000	2.20	0.50
4 "	0.27	0.64	60,000	205,000	1.00	4.00
6 "	0.52	0.64	32,000	177,000	2.50	0.20
8 "	0.61	0.46	32,000	45,000	1.50	2.00
10 "	0.18	0.39	35,000	27,000	1.50	0.80
12 "	0.30	0.25	49,000	44,000	1.25	1.50
14 "	0.23	0.39	30,000	24,000	1.00	1.50
16 "	1.00	0.13	20,000	22,000	2.00	1.20
18 "	0.67	0.11	35,000	20,000	0.80	0.50
20 "	0.54	0.13	23,000	12,000	3.00	0.00
22 "	0.48	0.48	19,000	9,500	2.50	0.00
24 "	0.36	0.57	25,000	11,000	0.90	0.50
26 "	0.55	0.50	12,000	11,000	0.60	0.00
28 "	0.48	0.54	6,400	8,900	1.20	0.90
30 "	0.49	0.33	7,300	8,400	0.80	0.90
32 "	0.89	0.89	7,300	8,400	0.80	0.90
34 "	0.54	....	6,000	.....	2.00	1.50
36 "	1.57	....	10,000	.....	1.20	1.00
Averages,	0.53	0.43	168,000	204,000	2.22	1.25

Dissolved Oxygen.

Numerous samples of applied water and effluent were collected, from time to time, to determine the amount of "Dissolved Oxygen" in the water before and after filtration. The following table gives the results of these determinations:—

TABLE F.

Calendar Date of Collection.			AMOUNT OF DISSOLVED OXYGEN,—PER CENT. OF SATURATION.			
			Gate Chamber.	Settling Basin.	Filter No. 1.	Filter No. 2.
October	29,	1897	95.6	91.8	83.4	83.7
November	3,	"	85.5	83.4	81.4	81.0
"	12,	"	91.5	92.0	86.2	76.4
December	1,	"	90.5	91.6	81.4	96.0
"	10,	"	96.4	99.9	94.1	87.9
"	15,	"	95.7	90.8	80.5	81.3
"	22,	"	94.6	93.8	85.8	83.5
"	28,	"	91.3	90.2	87.4	86.2
January	6,	1898	98.7	97.6	90.4	91.2
"	12,	"	96.3	95.4	91.6	92.1
"	20,	"	84.9	88.1	85.8	80.2
"	28,	"	83.7	82.9	80.4	81.3
February	3,	"	91.4	89.6	83.7	84.3
"	9,	"	81.6	79.7	81.5	79.7
"	15,	"	91.5	86.8	87.3	81.3
"	21,	"	91.2	90.6	82.7	80.8
March	4,	"	92.4	91.6	85.4	86.3
"	11,	"	91.4	....	84.6	87.3
"	17,	"	92.6	90.9	86.4	87.3
"	26,	"	89.0	91.9	84.7	89.4
April	1,	"	92.2	89.3	82.2	83.2
"	4,	"	90.8	90.2	81.8	83.4
"	11,	"	89.8	90.2	87.3	86.2
"	22,	"	66.0	67.1	67.6	64.9
"	25,	"	96.9	92.6	80.9	77.3
May	2,	"	85.2	85.8	73.3	65.0
"	9,	"	100.0	98.3	100.0	67.4
"	16,	"	78.2	79.0	66.8	66.0
"	23,	"	88.1	87.4	55.2	48.0
June	6,	"	98.8	54.4	68.2	72.4
"	13,	"	91.0	85.0	37.1	51.5
"	20,	"	79.1	91.5	59.8	39.1
"	27,	"	94.7	81.1	57.8	53.9
July	5,	"	82.6	83.0	36.4	45.3
"	11,	"	96.4	94.4	58.7	66.6
"	18,	"	71.1	....	73.4	52.6
"	25,	"	100.0	100.0	67.0	69.1
August	1,	"	69.4	67.9	34.8	50.5
"	8,	"	61.1	60.4	37.2	43.9
"	15,	"	89.9	98.0	40.9	53.0

BACTERIAL EFFICIENCY AFTER SCRAPING.

In order to determine the efficiency of the sand filters directly after scraping, we occasionally collected biological samples, at short intervals of time, after the water began to flow from the effluent pipes. It must be remembered, in studying these records, that the filters were filled from below with filtered water. When first started, after scraping, a rate of 250,000 gallons per acre was maintained for fifteen minutes; the rate was then increased to 500,000 gallons, which was maintained for another fifteen minutes; at the expiration of each successive fifteen minutes the rate was increased half a million, until the desired operating rate was secured. The results of the bacterial determinations are given in the following table:—

TABLE G.

Bacteria in Effluents from Sand Filters, after Scraping.

Calendar Date, 1898.	Time.	Bacteria Per Cubic Centimeter.
June 16,	11.48 P. M.	*Valve No. 1, opened.
" 16,	11.52 "	628
" 17,	1.05 A. M.	186
" 17,	2.05 "	210
" 17,	3.18 "	142
" 17,	4.06 "	690
" 17,	5.05 "	364
" 17,	6.05 "	628
" 17,	7.00 "	560
" 17,	8.00 "	374
" 17,	9.10 "	576
" 17,	11.00 "	770
" 17,	1.00 P. M.	840
" 17,	3.40 "	896
" 17,	6.15 "	204
" 17,	9.45 "	186
" 17,	12.00 A. M.	266
" 18,	3.16 "	576
" 18,	6.00 "	171
June 22,	1.23 A. M.	Valve No. 2, opened.
" 22,	1.28 "	240
" 22,	4.03 "	143
" 22,	6.00 "	122
" 22,	7.00 "	90
" 22,	8.10 "	171
" 22,	9.20 "	131
" 22,	11.03 "	199

*Crack in wall, between Settling Basin and Filter No. 1, was repaired upon July 15, 1898. See Page 120.

Calendar Date, 1898.	Time.	Bacteria Per Cubic Centimeter.
June 22,	1.15 P. M.	98
" 22,	4.06 "	136
" 22,	6.22 "	143
" 22,	10.10 "	58
July 19,	1.00 A. M.	Valve No. 1, opened.
" 19,	1.05 "	862
" 19,	2.00 "	199
" 19,	3.22 "	132
" 19,	4.00 "	169
" 19,	5.00 "	291
" 19,	6.00 "	184
" 19,	7.00 "	416
" 19,	8.00 "	354
" 19,	9.20 "	544
July 9,	7.25 P. M.	Valve No. 2, opened.
" 9,	7.27 "	852
" 9,	9.28 "	436
" 9,	10.15 "	251
" 9,	11.19 "	205
" 10,	12.15 A. M.	546
" 10,	2.15 "	562
" 10,	3.24 "	221
" 10,	4.15 "	718
" 10,	5.15 "	692
" 10,	6.15 "	492
" 10,	7.15 "	496
" 10,	9.14 "	430
" 10,	12.21 P. M.	272
" 10,	3.21 "	304
" 10,	6.25 "	230
" 10,	10.21 "	762
" 11,	12.06 A. M.	144
" 11,	3.20 "	145
" 11,	6.00 "	84
" 11,	9.17 "	74
" 11,	3.20 P. M.	80
" 11,	9.35 "	64
" 12,	3.37 A. M.	198
Aug. 21,	11.30 P. M.	Valve No. 2, opened.
" 21,	11.32 "	238
" 22,	1.30 A. M.	106
" 22,	3.30 "	197
" 22,	5.30 "	258
" 22,	7.30 "	319
" 22,	9.23 "	301
" 22,	12.00 M.	262
" 22,	3.00 P. M.	240
" 22,	6.00 "	215
" 22,	9.10 "	175

NOTE:—The turbidity and average numbers of bacteria in the applied water, at the time of the above tests, were as follows:—

Date, 24 Hours Ending 9.00 A. M.			Gate Chamber.		Settling Basin.	
			Turbidity.	Bacteria Per C. C.	Turbidity.	Bacteria Per C. C.
June	17,	1898	0.42	7,650	....	.....
"	18,	"	0.21	4,250	0.17	.....
"	22,	"	0.70	15,600	....	.....
"	23,	"	0.42	5,950	....	.....
July	9,	"	0.05	10,350	0.04	11,900
"	10,	"	0.05	8,100	0.03	6,100
"	11,	"	0.04	10,250	0.04	.....
"	12,	"	0.04	3,850	0.03	2,000
"	19,	"	0.06	14,400	0.15	16,000
August	22,	"	0.50	22,700	0.50	11,100
"	23,	"	0.31	12,600	0.22	5,450

Tabulation of Results.

The tables presented upon the following pages give the quantitative and biological results secured, by days; also the totals and averages for each month, and for the periods between scrapings. The results of the chemical analyses are given in Appendix No. 2, page 246 et seq.

RECORD OF SAND FILTER No. 1,

For the Month of July, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
2	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
17	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
18	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
21	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
22	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
23	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
24	20.0	11,500	2 080 000 / 1 740 000	.....	.....	.....	.....	8,260	4.830	6,860
25	24.0	12,700	1,910,000	0.10	.....	.....	.....	2,400	1,150	4,600
26	24.0	13,000	1,950,000	.....	.....	.....	.....	.....	.....	...
27	22.3	11,000	1 780 000 / 1 650 000	0.17	0.50	0.33	.....	1,300	1,450	750
28	24.0	12,960	1,950,000	0.20	0.52	0.31	.....	3,850	2,200	1,200
29	24.0	12,600	1,890,000	0.23	0.57	0.36	.....	4,200	2 800	900
30	24.0	13,010	1,960,000	0.27	0.52	0.36	.....	3,250	3,100	500
31	24.0	13,000	1,950,000	0.31	0.40	0.29	... ..	3,900	1,525	85
Totals,	186 3	99,770	14,990,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.3	12,470	1,880,000	.....	0.50	0.33	.....	3,880	2,436	2,128

NOTES:—Percentage of Bacteria removed, 45.2.

The rates of filtration for Filter No. 1 were computed by dividing the "Total Passed" by 0.00664. This figure represents the area of the sand surface, calculated from the preliminary measurements of the basin and gives rates slightly in error. These results, at first about one per cent. too small, gradually increased to about six per cent. for the last month of the experiments, due to the fact that the area decreased as sand was removed by scraping.

Where two numbers are given for a certain date in the "Rate" column, the upper one gives the rate of filtration for the actual time in operation. The lower figure gives the rate for twenty-four hours and has been used in computing the total for the month.

RECORD OF SAND FILTER No. 1,

For the Month of August, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	12,970	1,950,000	0.38	0.22	0.20	.....	7,250	1,675	46
2	24.0	13,220	1,990,000	0.47	0.11	0.15	.....	.....	. ....	...
3	24.0	13,160	1,980,000	0.52	0.09	0.09	.....	725	1,000	104
4	24.0	13,100	1,970,000	0.60	0.08	0.08	.....	900	825	48
5	24.0	13,190	1,980,000	0.66	0.08	0.08	.....	675	1,450	79
6	24.0	13,260	2,000,000	0.72	0.10	0.07	.....	750	1,275	54
7	24.0	13,320	2,000,000	0.83	.....	.....	.....	825	250	12
8	24.0	13,200	1,990,000	0.96	0.07	0.07	.....	625	2,275	40
9	24.0	13,170	1,980,000	1.10	0.10	0.06	.....	.....	.....	...
10	24.0	13,160	1,980,000	1.21	0.08	0.03	.....	625	575	16
11	24.0	13,440	2,020,000	1.34	0.06	0 01	.....	575	375	28
12	24.0	12,850	1,930,000	1.61	0.80	0 17	.....	4,075	850	84
13	24.0	12,460	1,870,000	2.00	.....	.....	.....	.....	.....	...
14	24.0	13,130	1,980,000	2.54	1.00	0.44	.....	4,400	3,500	28
15	24.0	13,110	1,970,000	3.13	0.21	0.23	.....	1,875	1,100	68
16	24.0	18,860	2,840 000	4.20	0.16	0.18	.....	.....	.....	...
17	22.0	9 840	1 610 000 1 480 000	5.52	0.15	0.14	.....	2.150	675	50
18	20.0	*15,300	2 760 000 2 300 000	.....	.....	.....	.....	6,250	1,375	64
19	24 0	19,730	2,970,000	0.21	0.12	0.30	.....	2,075	2,025	44
20	24.0	19,840	2,990,000	0.28	0.17	0.36	. ....	6,400	4,150	43
21	24.0	20,080	3,030,000	0.25	.....	.....	.....	2,200	2,085	67
22	24.0	19,800	2,980,000	0.29	.....	.....	.....	.....	.....	...
23	24.0	19,530	2,940,000	0.31	0.12	0.08	.....	1,300	900	82
24	24.0	18,870	2,840,000	0.32	0.08	0 06	.....	500	850	28
25	24.0	18,880	2,840,000	0.30	.....	.....	.....	1,150	1,025	35
26	24.0	18,310	2,760,000	0.30	.....	.....	.....	1,300	1,150	30
27	24.0	19,830	2,990.000	0.30	.....	.....	.....	1,325	1,237	21
28	24.0	19,940	3,000,000	0.25	.....	.....	.....	975	335	22
29	24.0	19,570	2,950.000	0.25	0.08	0.02	.....	950	300	41
30	24.0	19,860	2,990,000	0.32	.....	.....	.....	.....	.....	...
31	24.0	19,990	3,010,000	0.25	0.02	0.01	.....	2,362	825	21
Totals,	738.0	494,970	74,500,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.8	15,970	2,400,000	.....	0.19	0.13	.....	2,089	1,283	46

NOTES:—Percentage of Bacteria removed, 97.80.
* First Scraping; 0.04 feet removed, 325,210 gallons passed (48,909,000 per acre) since beginning.

RECORD OF SAND FILTER No. 1,

For the Month of September, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,990	3,010,000	0.25	0.02	0.01	.....	1,225	1,100	17
2	24 0	19,900	3,000,000	0.25	0.05	0.03	.....	3,050	1,212	21
3	24.0	19,960	3,010,000	0.30	0.09	0.04	.....	3,075	975	26
4	24.0	19,970	3,010,000	0.29	0.04	0.04	.....	2,536	1,150	22
5	24.0	19,960	3,010,000	0.27	0.04	0.04	.....	2,125	800	14
6	24.0	20,000	3,020,000	0.28	0.04	0.04	.....	.....	.....	...
7	24.0	19,350	2,910,000	0.30	.....	.....	.....	1,550	625	22
8	24.0	19,820	2,980,000	0.32	0.04	0.03	.....	2,400	962	13
9	24.0	19,730	2,970,000	0.37	0.05	0.04	.....	.....	1,350	8
10	24.0	19,800	2,980,000	0.45	.....	.....	.....	4,538	3,100	10
11	24.0	19,810	2,980,000	0.44	0.03	0.03	.....	1,613	1,350	9
12	24.0	19,800	2,980,000	0.43	.....	.....	.....	625	1,050	8
13	24.0	19,860	2,990,000	0.40	0.04	0.03	.....	.....	.....	...
14	24.0	19,870	2,990,000	0.37	.....	.....	.....	4,950	975	7
15	24.0	19,830	2,990,000	0.34	0.03	0.04	.....	1,545	720	6
16	24.0	19,790	2,980,000	0.39	0.04	0.03	.....	1,593	875	12
17	24.0	19,910	3,000,000	0.42	0.04	0.03	.....	1,650	225	15
18	24.0	19,810	2,980,000	0.53	0.07	0.04	.....	2,170	690	30
19	24.0	19,760	2,980,000	0.65	0.05	0.04	.....	1,900	650	14
20	24.0	19,780	2,980,000	0.76	.....	.....	.....	3,225	2,000	18
21	24.0	19,780	2,980,000	1.00	0.05	0.04	.....	1,225	1,041	27
22	24.0	19,840	2,990,000	1.22	0.09	0.05	.....	700	587	10
23	24.0	19,910	3,000,000	1.45	0.04	0.04	.....	2,275	825	7
24	24.0	19,830	2,990,000	1.58	0.05	0.04	.....	3,125	2,275	19
25	24.0	19,840	2,990,000	1.80	0.05	0.04	.....	2,250	2,100	26
26	24.0	19,850	2,990,000	2.13	0.05	0.05	.....	9,575	3,925	12
27	24.0	19,590	2,950,000	2.32	.....	.....	.....	.....	.....	...
28	24.0	19,760	2,970,000	2.64	.....	.....	.....	1,750	1,112	18
29	24.0	19,710	2,970,000	2.96	0.06	0.04	.....	1,667	667	14
30	24.0	19,890	2,990,000	3.24	0.07	0.06	.....	2,100	900	24
Totals,	720.0	594,700	89,570,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	24.0	19,820	2,980,000	.....	0.05	0.04	.....	2,478	1,231	16

NOTE:—Percentage of Bacteria removed, 99.35.

RECORD OF SAND FILTER No. 1,

For the Month of October, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	20,100	3,030,000	3.56	0.08	0.06	.....	4,549	2,200	14
2	24.0	19,710	2,970,000	3.76	0.06	0.05	.....	5,525	2,400	32
3	24.0	19,950	3,000,000	4.25	0.05	0.05	.....	5,625	2,975	18
4	24 0	19,700	2,970,000	4.26	.....	.....	.....	.....	.....	...
5	24.0	19,770	2,980,000	4.56	0.05	0.05	.....	3,362	3,300	12
6	24.0	19,800	2,980,000	4.83	0.05	0.04	.....	1,876	2,237	15
7	24.0	19,820	2,980,000	5.32	0.04	0.03	.....	18,550	2,700	15
8	24.0	19,890	2,990,000	6.07	0.04	0.03	.....	17,363	6,500	25
9	24.0	19,750	2,970,000	7.01	0.03	0.03	.....	62,325	58,750	23
10	3.7	* 60	60 000 / 10 000	.....	0.03	0.03	.....	20,550	14,000	24
11	23.6	19,400	2 970 000 / 2 920 000	0.40	0.03	0.03	.....	22,575	.....	177
12	24.0	20,080	3,030,000	0.35	0.03	0.03	.....	13,700	12,562	84
13	24.0	19,910	3,000,000	0.34	0.03	0.03	.....	14,675	16,100	35
14	24.0	20,050	3,020,000	0.33	0.03	0.03	.....	17,150	12,000	26
15	24.0	20,100	3,030,000	0.34	0.03	0.03	.....	27,300	19,000	26
16	24.0	20,060	3,020,000	0.34	0.03	0.02	.....	19,950	16,475	24
17	24.0	20,100	3,030,000	0,26	0.03	0.02	.....	29,750	7,813	19
18	24.0	20,100	3,030,000	0.30	0.03	0.03	.....	.....	.....	...
19	24.0	20,090	3,030,000	0.33	.....	.....	.....	76,913	51,025	25
20	24.0	20,050	3,020,000	0.37	0.03	0.03	.....	93,450	53,175	21
21	24.0	19,980	3,010,000	0.40	0.03	0.03	.....	99,600	58,500	22
22	24 0	19,890	2,990,000	0.43	0.03	0.03	.....	159,500	76,500	17
23	24.0	19,830	2,990,000	0.47	0.03	0.02	.....	151,250	47,250	16
24	24.0	19,850	2,990,000	0.53	0.03	0.03	.....	196,500	58,050	17
25	24.0	19,810	2,980,000	0.59	0.03	0.02	.....	.....	.....	...
26	24.0	20,090	3,030,000	0.67	0.03	0.02	.....	94,500	45,875	22
27	24.0	19,910	3,000,000	0.74	0.03	0.02	.....	118,500	44,075	21
28	24.0	19,900	3,000,000	0.84	0.03	0.02	.....	155,000	89,375	28
29	24.0	20,060	3,020,000	0.92	0.02	0.02	.....	206,500	102,125	51
30	24.0	19,990	3,010,000	1.05	0.02	0.02	.....	183,750	119,000	40
31	24.0	19,800	2,980,000	1.17	.....	.....	.....	220,300	134,062	61
Totals,	723.3	597,600	90,010,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.3	19,280	2,900,000	.....	0 04	0.04	.....	72,878	39,186	32

NOTES:—Percentage of Bacteria removed, 99.96.
* 2d Scraping; 0.06 feet removed, 1,042,780 gallons passed (157,040,000 per acre) since 1st Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of November, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,940	3,000,000	1.33	0.03	0.02	.....	.....	.....	...
2	24.0	19,940	3,000,000	1.54	0.03	0.03	.....	111,000	103,250	45
3	24.0	19,780	2,980,000	1.71	0.06	0.04	.....	.....	90,000	20
4	24.0	20,000	3,010,000	1.89	0.04	0 03	.....	66,475	50,300	35
5	24.0	19,750	2,970,000	2.06	0.04	0.04	.....	72,875	76,525	26
6	24.0	19,950	3,000,000	2.19	0.05	0.03	.....	27,000	72,500	31
7	24.0	19,810	2,980,000	2.38	0.06	0.04	.....	16,063	41,913	32
8	24,0	19,990	3,010,000	2.65	0.04	0.04	.....	.....	.....	...
9	24.0	19,850	2,990,000	2.87	0.04	0.05	.....	7,850	17,425	26
10	24.0	19,750	2,970,000	3.05	0.16	0.10	.....	8,550	13,288	24
11	24.0	19,840	2,990,000	3.38	0.08	0.06	.....	6,375	4,600	22
12	24.0	19,830	2,990,000	3.65	0.11	0.08	.....	.....	.....	...
13	24.0	19,400	2,920,000	4.19	0.23	0.10	.....	6,500	6,113	53
14	22.0	14,610	2 400 000 2 200 000	4.82	.....	.....	.....	8,100	8,310	85
15	2.5	330	480 000 50 000	.....	. ....	.....	.....	.....	.....	.....
16	0.0	0	0	.....	.....	.....	... ..	.....	.....	.....
17	0.0	* 0	0	.....	0.70	0.70	.....	21,350	15,700	643
18	20.6	15,560	2 720 000 3 340 000	0.35	1.00	0.44	.....	29,900	21,325	843
19	24.0	19,960	3,010,000	0.50	0.88	0.50	.....	17,950	24,400	1,701
20	24.0	19,730	2,970,000	0.73	0.42	0.39	.....	21,950	20,700	1,288
21	24.0	19,720	2,970,000	0.93	0.26	0.25	.....	23,050	23,125	1,041
22	24.0	19,770	2,980,000	1.17	0.16	0.18	.....	16,800	18,800	784
23	24.0	19,540	2,940,000	1.31	0.09	0.13	.....	21,100	25,450	473
24	24.0	19,830	2,990,000	1.51	0.08	0.10	.....	15,150	24,350	383
25	24.0	19,870	2,990,000	1.62	0.08	0.10	.....	12,475	12,200	236
26	24.0	19,940	3,000,000	1.72	0.08	0.08	.....	10,050	8,300	142
27	24.0	19,860	2,990,000	1.76	0.07	0.05	.....	8,625	6,400	160
28	24.0	19,550	2,940,000	1.92	0.09	0.08	.....	17,800	10,750	82
29	24.0	19,890	2,990,000	2.21	1.00	0.20	.....	.....	.....	.....
30	24.0	19,520	2,940,000	2.65	0.50	0.44	.....	33,075	22,450	137
Totals,	645.1	525,510	79,110,000	.....	.....	.....	.....	.....	.....	.....
Av'gs,	21.5	17,520	2,640,000	.....	0.24	0.16	.....	25,220	29,924	346

NOTES:—Percentage of Bacteria removed, 98.63.
* 3d Scraping; 0.05 feet removed, 691,820 gallons passed (104,190,000 per acre) since 2d Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of December, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	20,170	3,040,000	3.17	0.26	0.25	.....	36,000	20,000	130
2	24.0	19,920	3,000,000	3.39	0.24	0.22	.....	23,300	21,350	196
3	24.0	20,110	3,030,000	3.63	0.16	0.16	.....	17,900	15,550	201
4	24.0	19,880	2,990,000	3.72	0.09	0.10	.....	17,250	14,200	140
5	24.0	19,900	3,000,000	3.86	0.07	0.08	.....	11,450	9,450	143
6	24.0	20,030	3,020,000	4.05	0.21	0.13	.....	.... .	.....	...
7	24.0	19,980	3,010,000	4.11	0.36	0.10	.....	28,850	16,925	126
8	22.5	17,000	2 730 000 / 2 560 000	4.21	0.33	0.15	.....	24,400	28,350	85
9	1.7	* 1,140	2 400 000 / 170 000	.....	.....	.....	.....	20,050	31,300	...
10	24.0	18,890	2,850,000	0.99	0.14	0.15	.....	21,100	33,200	643
11	24.0	17,760	2,670,000	2.35	.....	.....	.....	25,700	46,600	307
12	24.0	19,580	2,950,000	2.71	0.10	0.12	.....	8,025	17,400	231
13	24.0	20,650	3,110,000	2.34	0.09	0.09	.....	16,400	.....	...
14	24.0	20,050	3,020,000	1.31	0.09	0.08	.....	7,800	11,325	81
15	24.0	20,020	3,020,000	1.26	0.09	0.07	.....	7,975	11,225	57
16	24.0	19,910	3,000,000	1.35	0.38	0.11	.....	15,400	10,850	49
17	24.0	19,880	2,990,000	1.48	0.50	0.20	.....	25,475	14,750	97
18	24.0	19,690	2,970,000	1.75	0.50	0.33	.....	16,350	15,675	84
19	24.0	19,780	2,980,000	2.09	0.33	0.26	.....	11,800	8,400	69
20	24.0	19,870	2,990,000	2.26	0.19	0.20	.....	13,700	7,350	99
21	24.0	19,810	2,980,000	2.04	0.13	0.18	.....	.....	18,500	...
22	24.0	20,060	3,020,000	2.52	0.12	0.13	.....	.....	.....	...
23	24.0	19,660	2,960,000	2 67	0.40	0.24	.....	13,050	11,650	126
24	24.0	19,820	2,980,000	3.15	0.14	0.17	.....	7,650	10,550	150
25	24.0	20,110	3,030,000	3.45	0.11	0.16	.....	5,025	7,700	177
26	24.0	19,790	2,980 000	3.61	0.10	0.10	.....	.....	.....	...
27	24.0	19,730	2 970,000	3.79	0.07	0.07	.....	2,500	2,350	57
28	21.7	16,780	2 790 000 / 2 530 000	3.99	0.06	0.06	.....	2,750	4,950	64
29	0.0	† 0	0	.....	0.06	0.05	.....	1,900	5,050	93
30	23.4	19,000	2 930 000 / 2 860 000	0.35	0.06	0.05	.....	4,000	3,950	265
31	24.0	19,900	3,000,000	0.35	0.05	0.04	.....	3,900	4,325	398
Totals,	693.3	568,870	85,680,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.4	18,350	2,760,000	.....	0.19	0.14	.....	14,433	14,923	163

NOTES:—Percentage of Bacteria removed, 98.87.
* 4th Scraping; 0.05 feet removed, 409,730 gallons passed (61,700,000 per acre) since 3d Scraping.
† 5th " 0.13 " " 372,980 " " (56,170,000 " ") " 4th "

RECORD OF SAND FILTER No. 1.

For the Month of January, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,910	3,000,000	0.32	0.05	0.05	.....	2,000	6,850	239
2	24.0	19,870	2,990,000	0.36	0.05	0.05	.....	4,150	2,900	279
3	24.0	19,810	2,980,000	0.38	0.03	0.04	.....	.....	.....	...
4	24.0	19,700	2,970,000	0.66	0.04	0.04	.....	1,625	2,425	202
5	24.0	19,880	2,990,000	0.86	0.03	0.03	.....	3,675	4,750	210
6	24.0	19,730	2,970,000	1.18	.....	.....	.....	3,125	5,950	206
7	24.0	19,910	3,000,000	1 58	0.04	0.04	.....	3,950	5,625	199
8	24.0	19,720	2,970,000	1.95	0.22	0.03	.....	8,675	5,600	216
9	24.0	19,650	2,960,000	2.41	0.73	0.13	.....	21,500	11,300	208
10	24.0	19,400	2,920,000	3.02	0.30	0.33	.....	12,550	.....	350
11	23.7	18,710	2 860 000 2 820 000	3.98	0.30	0.21	.....	16,175	16,525	385
12	1.6	* 990	2 260 000 150 000	.....	0.43	0.12	.....	11,375	11,000	233
13	24.0	19,410	2,920,000	0.43	0.57	0.15	.....	16,125	13,450	381
14	24.0	19,870	2,990,000	0.55	0.89	0.38	.....	30,987	19,100	358
15	24.0	20,030	3,020,000	0.71	0.84	0.35	.....	40,350	37,650	518
16	24.0	19,740	2,970,000	0.96	0.48	0.33	.....	45,325	28,925	756
17	24.0	19,780	2,980,000	1.20	0.53	0.30	.....	.....	.....	...
18	24.0	20,000	3,010,000	1.49	0.26	0.22	.074	21,275	32,875	510
19	24.0	19,740	2,970,000	1.62	0.20	0.19	.045	22,700	23,300	297
20	24.0	20,110	3,030,000	1.85	0.12	0.12	.045	11,000	15,650	252
21	24.0	19,830	2,990,000	1.98	0.16	0.10	.036	12,300	12,650	184
22	24.0	19,760	2,980,000	2.25	0.16	0.13	.023	19,000	13,900	119
23	24.0	19,790	2,980,000	2.46	0.19	0.14	.015	20,450	11,450	112
24	24.0	19,430	2,930,000	2.98	0.30	.....	.015	23,750	17,000	211
25	24.0	17,020	2,500,000	4.16	0.50	.....	.045	26,150	.....	297
26	0.6	† 420	2 400 000 60 000	.....	0.19	. ....	.036	12,650	.....	658
27	23.2	18,570	2 900 000 2 800 000	0.52	0.25	0.19	.011	15,000	15,550	561
28	24.0	19,790	2,980,000	0.80	0.22	0.19	.030	14,050	13,950	625
29	24.0	19,780	2,980,000	0.81	0.11	0.12	.030	6,825	10,400	478
30	24.0	19,990	3,010,000	1.04	0.08	0.09	.. ...	2,600	6,925	299
31	24.0	19,660	2,960,000	1.26	0.09	0.08	.....	.....	.....	...
Totals,	697.1	570,000	85,840,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.5	18,390	2,770,000	.....	0.27	0.15	.....	15,333	13,828	334

Notes:—Percentage of Bacteria removed, 97.82.

* 6th Scraping; 0.03 feet removed, 255.190 gallons passed; (38,430,000 per acre) since 5th Scraping.
† 7th " 0.05 " " 255,500 " " (38,480,000 ") " 6th "

RECORD OF SAND FILTER No. 1,

For the Month of February, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,820	2,980,000	1.55	0.08	0.07	.011	2,350	5,200	152
2	24.0	19,750	2,970,000	1.87	0.08	0.08	.003	2,250	3,975	91
3	24.0	19,670	2,960,000	2.20	0.09	0.08	.....	2,775	4,050	128
4	24.0	19,760	2,980,000	2.59	0.06	0.08	.003	2,700	3,825	67
5	24.0	19,700	2,970,000	2.95	0.05	0.09	.003	1,575	5,075	87
6	24.0	19,610	2,950,000	3.44	0.05	0.04	.003	1,425	1,925	79
7	23.3	17,210	2 670 000 / 2 590 000	3.86	.....	.....	.....	.....	.....	...
8	10.4	*7,610	2 650 000 / 1 150 000	.....	0.04	0.03	.....	1,700	1,775	...
9	24.0	20,570	3,100,000	0.31	0.04	0.03	.....	3,550	3,700	119
10	24.0	20,340	3,060,000	0.30	0.14	0.04	.003	.....	.....	...
11	24.0	20,300	3,060,000	0.30	0.26	0.10	.001	.....	.....	...
12	24.0	20,280	3,050,000	0.31	0.30	0.16	.004	8,025	8,425	154
13	24.0	19,820	2,980,000	0.40	0.48	0.19	.....	17,500	14,300	148
14	24.0	20,280	3,050,000	0.60	0.47	0.20	.....	.....	.....	...
15	24.0	20,150	3,040,000	0.82	0.32	0.19	.023	25,600	33,600	710
16	24.0	19,880	2,990,000	0.90	0.25	0.19	.045	24,150	27,050	753
17	24.0	19,900	3,000,000	1.06	0.19	0.19	.030	23,600	29,000	932
18	24.0	20,290	3,060,000	1.21	0.13	0.14	.023	9,250	12,450	735
19	24.0	19,880	2,990,000	1.30	0.09	0.10	.023	11,025	13,575	458
20	24.0	19,730	2,970,000	1.45	0.08	0.07	.015	7,050	10,700	270
21	24.0	20,410	3,070,000	1.62	.....	.....	.....	.....	.....	...
22	24.0	20,250	3,050,000	1.72	0.16	0.10	.010	12,025	11,375	133
23	24.0	20,140	3,030,000	1.85	0.15	0.12	.010	10,150	16,250	95
24	24.0	19,900	3,000,000	1.98	0.13	0.14	.010	12,350	10,350	96
25	24.0	19,900	3,000,000	2.10	0.11	0.13	.....	9,400	14,800	111
26	24.0	19,820	2,980,000	2.11	0.08	0.08	.010	12,112	19,775	157
27	24.0	19,720	2,970,000	2.15	0.07	0.08	.015	7,750	13,775	103
28	24.0	19,850	2,990,000	2.22	0.05	0.06	.....	8,600	.....	...
Totals,	657.7	544,540	81,990,000	.....	.. ...	.....	.....	.....	.....	...
Av'gs,	23.5	19,450	2,930,000	.....	0.15	0.11	.013	9,430	12,043	266

NOTES:—Percentage of Bacteria removed, 97.18.
* 8th Scraping; 0.10 feet removed, 233,730 gallons passed (35,190,000 per acre) since 7th Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of March, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,940	3,000,000	2.27	0.04	0.06	.010	6,125	13,825	122
2	24.0	19,840	2,990,000	2.35	0.05	0.06	.010	7,650	17,250	78
3	24.0	20,230	3,050,000	2.47	.....	.....	.010	7,450	13,625	65
4	24.0	20,060	3,020,000	2.56	0.05	0.05	.006	4,925	4,875	59
5	24.0	19,790	2,980,000	2.66	0.06	0.05	.010	4,475	4,725	55
6	24.0	19,120	2,880,000	2.73	0.07	0.05	.010	5,150	6,225	26
7	24.0	20,280	3,050,000	3.02	.....	.....	.....	3,400	.....	...
8	24.0	20,040	3,020,000	3.15	0.04	0.05	.004	5,100	7,350	38
9	24.0	20,010	3,010,000	3.19	0.05	0.05	.006	5,075	5,750	52
10	24.0	17,830	2,690,000	3.30	0.05	0.05	.010	5,175	6,425	40
11	8.4	*5,810	2 490 000 / 870 000	.....	0.06	0.06	.....	5,700	8,650	48
12	24.0	20,440	3,080,000	0.40	0.05	.....	.001	5,475	.....	115
13	24.0	20,520	3,090,000	0.32	0.05	0.06	.....	6,525	8,300	70
14	24.0	20,470	3,080,000	0.37	0.08	0.08	.....	.....	.....	...
15	24.0	20,450	3,080,000	0.30	0.12	0.06	.006	12 025	13,000	39
16	24.0	20,350	3,070,000	0.38	0.12	0.08	.006	14,175	15,100	115
17	24.0	20,170	3,040,000	0.39	0.11	0.09	.010	12,400	12,750	80
18	24.0	19,760	2,980,000	0.40	0.10	0.09	.010	7,350	9,900	43
19	24.0	20,220	3,050,000	0.44	0.09	0.09	.015	8,600	10,000	74
20	24.0	20,220	3,050,000	0.43	0.08	0.09	.006	9,900	6,250	47
21	24.0	20,050	3,020,000	0.46	0.49	0.09	.010	.....	.....	...
22	24.0	20,150	3,040,000	0.49	0.90	0.17	.010	.....	.....	...
23	24.0	20,020	3,020,000	0.58	1.00	0.50	.010	56,000	32,200	35
24	24.0	20,120	3,030,000	0.70	2.38	0.70	.045	55,483	30,717	62
25	24.0	19,870	2,990,000	0.90	0.90	0.80	.045	23,267	33,333	145
26	24.0	20,200	3,040,000	1.27	0.41	0.70	.066	14,400	21,500	229
27	24.0	19,830	2,990,000	1.52	0.20	0.19	.030	7,000	8,500	77
28	24.0	20,320	3,060,000	1.62	0.17	0.15	.....	4,800	9,050	68
29	24.0	20,120	3,030,000	1.95	0.20	0.16	.004	4,750	7,316	94
30	24.0	19,870	2,990,000	1.97	0.29	0.18	.004	9,967	5,000	24
31	24.0	20,120	3,030,000	2.28	0.50	0.20	.010	16,583	9,400	28
Totals,	728.4	606,220	91,320,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.5	19,560	2,950,000	.....	0.30	0.18	.014	11,747	12,347	71

NOTES:—Percentage of Bacteria removed, 99.40.
*9th Scraping; 0.07 feet removed, 606,430 gallons passed (91,320,000 per acre) since 8th Scraping.
*270 gallons passed before and 5,540 gallons after Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of April, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	20,530	3,090,000	2.64	0.18	0.21	.006	8,500	6,900	50
2	24.0	20,200	3,040,000	2.69	0.17	0.24	.010	5,375	7,700	27
3	24.0	19,810	2,980,000	2.87	0.13	0.16	.010	5,287	7,850	21
4	24.0	20,470	3,080,000	3.20	0.11	0.13	.....	3,667	7,450	26
5	24.0	20,040	3,020,000	3.33	0.08	0.11	.010	2,937	4,875	31
6	24.0	18,900	2,850,000	3.61	0.07	0.09	.003	2,512	3,875	28
7	6.2	* 3,530	[2] 050 000 / 530 000	.....	0.07	0.09	.006	2,562	4,825	19
8	24.0	20,220	3,050,000	0.40	0.08	0.07	.003	1,725	4,627	58
9	24.0	20,590	3,100,000	0.28	0.07	0.06	.004	2,112	1,250	43
10	24.0	20,650	3,110,000	0.27	0.05	0.05	.006	2,925	3,350	31
11	24.0	20,440	3,080,000	0.29	0.04	0.05	.....	2,917	2,400	31
12	24.0	20,330	3,060,000	0.45	0.04	0.06	.001	3,037	2,550	25
13	24.0	20,480	3,080,000	0.39	0.04	0.05	.001	3,575	2,975	31
14	24.0	20,150	3,040,000	0.47	0.04	0.04	.001	2,537	3,150	34
15	24.0	20,050	3,020,000	0.56	0.04	0.04	.001	2,980	2,650	33
16	24.0	20,050	3,020,000	0.61	0.04	0.04	.001	2,612	2,175	27
17	24.0	20,090	3,030,000	0.66	0.03	0.04	.001	1,525	2,025	22
18	24.0	20,040	3,020,000	0.68	0.06	0.04	.....	2,317	1,350	39
19	24.0	20,000	3,010,000	0.70	0.05	0.04	.....	2,525	2,300	30
20	24.0	19,850	2,990,000	0.77	0.04	0.04	.001	2,750	1,650	32
21	24.0	19,680	2,960,000	0.90	0.06	0.05	.001	2,162	1,575	22
22	24.0	20,250	3,050,000	1.09	0.05	0.05	.001	1,537	1,775	40
23	24.0	20,270	3,050,000	1.28	0.04	0.04	.001	1,425	1,150	25
24	24.0	20,040	3,020,000	1.40	0.04	0.04	.001	2,410	1,350	37
25	24.0	20,000	3,010,000	1.54	0.06	0.04	.....	7,350	1,350	55
26	24.0	19,840	2,990,000	1.65	0.20	0.06	.001	16,000	7,150	26
27	24.0	20,250	3,050,000	1.89	0.23	0.12	.001	18,912	9,800	28
28	24.0	20,120	3,030,000	1.96	0.21	0.15	.001	17,725	11,225	25
29	24.0	20,000	3,010,000	2.07	0.12	0.11	.001	10,587	9,725	54
30	24.0	20,350	3,060,000	2.21	0.09	0.10	.003	7,812	7,925	44
Totals,	702.2	587,220	88,430,000	.....	.....	.....	.....	.....	.....	.....
Av'gs,	23.4	19,570	2,950,000	.....	0.08	0.08	.003	5,010	4,928	33

NOTES:—Percentage of Bacteria removed, 99.34.
* 10th Scraping; 0.12 feet removed, 531,790 gallons passed (80,100,000 per acre) since 9th Scraping.
* 3030 gallons passed before and 500 gallons after Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of May, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	20,060	3,030,000	2.29	.....	0.07	.003	5,490	5,250	46
2	24.0	20,240	3,050,000	2.31	0.05	0.06	.....	4,380	4,600	60
3	24.0	19,990	3,010,000	2.35	0.03	0.04	.001	3,120	3,100	130
4	24.0	19,870	2,990,000	2.36	0.04	0.04	.001	4,090	2,050	53
5	24.0	20,000	3,010,000	2.44	0.05	0.04	.001	4,020	2,300	64
6	24.0	19,760	2,980,000	2.54	0.04	0.04	.001	3,350	1,420	46
7	24.0	20,150	3,040,000	2.71	0.04	0.04	.005	3,060	1,500	65
8	24.0	19 820	2,980,000	2.95	0.05	0.04	.002	4,720	2,100	88
9	24.0	19,790	2,980,000	3.25	0.17	0.04	.....	13,500	4,400	55
10	24.0	19,010	2,860,000	3.79	0.28	0.14	.002	19,400	5,550	77
11	24.0	15,340	2,310,000	4.16	0.10	0.13	.008	8,100	9,600	68
12	11.7	* 8,000	[2] 430 000 / 210 000	.....	0.05	0.09	.007	4,960	7,000	110
13	24.0	19,900	3,000,000	0.27	0.07	00.1	.007	4,310	4,950	84
14	24.0	20,040	3,020,000	0.26	0 04	0.08	.009	4,510	.....	73
15	24.0	20,010	3,010,000	0.22	0.06	0.07	.007	7,400	3,800	78
16	24.0	20,010	3,010,000	0.23	0.10	0.08	.....	7,050	3,650	125
17	24.0	20,060	3,020,000	0.22	0.20	0.06	.009	33,600	6,450	64
18	24.0	20,090	3,030,000	0.23	1.20	0.29	.013	55,000	16,600	51
19	24.0	20,030	3,020,000	0.25	0.40	0.55	.018	17,000	31,000	75
20	24.0	20,080	3,030,000	0.27	0.18	0.19	.025	12,500	12,700	108
21	24.0	20,050	3,020,000	0.29	0.18	0.11	.018	12,700	15,400	110
22	24.0	19,970	3,010,000	0.31	0.55	0.13	.020	22,800	10,900	98
23	24.0	20,020	3,020,000	0.31	0.40	0.23	.018	13,200	9,000	160
24	24.0	20,030	3,020,000	0.35	0.15	0.15	.025	13,900	6,400	110
25	24.0	20,040	3,020,000	0.35	0.50	0.17	.022	19,500	5,100	250
26	24.0	19,980	3,010,000	0.35	0.31	0.21	.020	12,500	6,950	160
27	24.0	19,990	3,010,000	0.37	0.19	0.18	.018	6,400	7,450	245
28	24.0	19,950	3,000,000	0.38	0.11	0.13	.020	3,840	5,300	350
29	24.0	20,010	3,010,000	0.37	0.09	0.10	.022	3,410	3,720	190
30	24.0	19,960	3,010,000	0.38	0.10	0.08	.022	4,070	2,750	96
31	24.0	19,930	3,000,000	0.38	0.05	0.06	.022	1,500	2,250	110
Totals,	731.7	602,180	90,710,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.6	19,430	2,930,000	.....	0.19	0.12	.012	10,800	6,770	110

NOTES:—Percentage of Bacteria removed, 98.98.
* 11th Scraping; 0.07 feet removed, 679,270 gallons passed (102,300,000 per acre) since 10th Scraping.
* 1,000 gallons passed before and 7,000 gallons after Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of June, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,870	2,990,000	0.38	0.07	0.05	.018	1,960	1,800	87
2	24.0	20,230	3,050,000	0.46	0.04	0.04	.015	1,700	1,220	73
3	24.0	20,180	3,040,000	0.44	0.06	0.04	.020	1,420	1,370	90
4	24.0	20,150	3,040,000	0.49	0.04	0.03	.015	3,020	2,450	170
5	24.0	20,140	3,030,000	0.49	0.03	0.03	.018	2,300	1,150	100
6	24.0	20,060	3,020,000	0.54	0.02	0.03	.....	3,540	2,050	205
7	24.0	20,010	3,010,000	0.60	0.02	0.03	.012	3,460	2,250	130
8	24.0	19,860	2,990,000	0.69	0.02	0.02	.012	12,000	5,900	235
9	24.0	20,150	3,040,000	0.96	0.02	0.02	.009	23,400	6,100	350
10	24.0	19,760	2,980,000	1.12	0.02	0.02	.007	17,400	10,100	130
11	24 0	20,420	3,070,000	1.56	0.02	0.02	.....	28,300	11,400	195
12	24.0	19,510	2,940,000	2.15	0.02	0.02	.005	19,500	9,200	160
13	24.0	19,830	2,990,000	2.67	0.02	0.02	.....	12,400	6,100	100
14	24.0	19,750	2,970,000	3.25	0.03	0.03	.005	21,200	5,500	92
15	24.0	15,070	2,270,000	4.16	0.70	0.20	.003	27,900	12,700	66
16	3.0	1,400	1 680 000 / 210 000	.....	0.80	0.20	.001	16,500	11,000	80
17	9.2	*7,000	2 740 000 / 1 050 000	.....	0.42	.....	.....	7,650	.....	385
18	24.0	20,000	3,010,000	0.23	0.21	.....	.010	4,250	.....	560
19	24.0	19,910	3,000,000	0.21	0.15	0.17	.010	6,150	.....	101
20	24.0	19,930	3,000,000	0.24	0.40	0.15	.013	28,900	5,300	75
21	24.0	19,930	3,000,000	0.21	0.65	0.27	.015	25,100	12,600	75
22	24.0	20,390	3,070,000	0.27	0.70	0.50	.013	15,600	12,900	67
23	24.0	20,480	3,080,000	0.34	0.42	0.40	.010	5,950	8,150	77
24	24.0	20,330	3,060,000	0.39	0.23	0.29	.013	3,500	4,770	81
25	24.0	20,460	3,080,000	0.36	0.12	0.16	.023	2,700	3,150	80
26	24.0	19,950	3,000,000	0.44	0.12	0.10	.010	4,980	2,150	135
27	24.0	19,930	3,000,000	0.48	0.11	0.08	.010	.....	.....	43
28	24.0	19,880	2,990,000	0.55	0.07	0.07	.008	3,770	2,500	49
29	24.0	20,040	3,020,000	0.61	0.07	0.06	.008	6,250	4,120	45
30	24.0	19,980	3,010,000	0.68	0.06	0.06	.007	11,200	8,250	46
Totals,	684.2	564,600	85,010,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.8	18,820	2,830,000	.....	0.19	0.11	.011	11,100	5,930	135

NOTES:—Percentage of Bacteria removed, 98.78.
* 12th Scraping; 0.07 feet removed, 683,540 gallons passed (102,970,000 per acre) since 11th Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of July, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	20 000	3,010,000	0.74	0.29	0.07	.002	6,000	4,750	33
2	24.0	19,880	2,990,000	0.80	0.22	0.12	.008	5,700	3,770	39
3	24.0	20,390	3,070,000	0.85	0.17	0.11	.008	5,250	2,700	71
4	24.0	20,250	3,050,000	1.01	0.11	0.09	.....	4,150	4,600	115
5	24.0	20,280	3,050,000	1.17	0.09	0.09	.....	3,150	3,000	47
6	24.0	19,900	3,000,000	1.35	0.05	0.06	.....	6,850	1,370	45
7	24.0	19,800	2,980,000	1.54	0.05	0.06	.007	6,350	4,350	49
8	24.0	19,830	2,990,000	1.74	0.08	0.09	.007	5,650	4,200	36
9	24.0	20,120	3,030,000	1.92	0.05	0.04	.003	10,350	11,900	61
10	24.0	19,860	2,990,000	2.10	0.05	0.03	.002	8,100	6,100	78
11	24.0	19,680	2,960,000	2.20	0.04	0.04	.....	10,250	.....	47
12	24.0	19,430	2,930,000	2.25	0.04	0.03	.002	3,850	2,000	49
13	24.0	19,980	3,010,000	2.49	0.05	0.04	.001	19,800	6,400	39
14	24.0	19,620	2,950,000	2.80	0.04	0.04	.001	40,500	14,900	38
15	24.0	20,280	3,050,000	3.03	0.03	0.03	.001	40,200	27,900	65
16	24.0	19,980	3,010,000	3.31	0.08	0.06	.001	42,600	29,000	73
17	24.0	19,260	2,900,000	3.42	0.80	0.14	.005	41,000	38,800	82
18	24.0	17,400	2,620,000	4.71	0.10	0.15	.001	35,200	26,400	64
19	8.7	* 6,760	2 810 000 / 1 020 000	.....	0.06	0.13	.....	14,400	18,100	290
20	24.0	20,420	3,080,000	0.23	0.07	0.13	.002	22,600	12,900	280
21	24.0	20,450	3,080,000	0.19	0.19	0.09	.002	24,500	15,200	67
22	24.0	20,490	3,090,000	0.19	0.11	0.10	.001	20,800	14,400	55
23	24.0	19,950	3,000,000	0.20	0.05	0.06	.000	15,200	20,200	58
24	24.0	19,710	2,970,000	0.18	0.03	0.05	.000	8,050	12,200	54
25	24.0	20 390	3,070,000	0.17	0.06	0.06	.....	14,600	11,700	44
26	24.0	20,670	3,110,000	0.17	0.06	0.06	.001	8,750	11,500	43
27	24.0	19,800	2,980,000	0.19	0.09	0.12	.000	16,500	9,900	41
28	24.0	20,100	3,030,000	0.19	0.06	0.06	.000	24,500	28,200	44
29	24.0	20,100	3,030,000	0.20	0.05	0.05	.000	18,500	13,700	43
30	24.0	20,160	3,040 000	0.21	0.05	0.04	.005	17,700	15,600	95
31	24.0	20,100	3,030,000	0.22	0.06	0.06	.000	20,100	14,500	135
Totals,	728.7	605,040	91,120,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.5	19,520	2,940,000	.....	0.11	0.07	.002	16,800	13,000	74

NOTES:—Percentage of Bacteria removed, 99.56.
* 13th Scraping; 0.09 feet removed, 624,610 gallons passed (94,030,000 per acre) since 12th Scraping.
* 460 gallons passed before and 6,300 gallons after Scraping.

RECORD OF SAND FILTER No. 1,

For the Month of August, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,620	2,950,000	0.21	0.42	0.14	...	48,200	26,100	72
2	24.0	19,740	2,970,000	0.24	0.70	0.50	.000	27,500	28,700	52
3	24.0	19 020	2,860,000	0.28	0.35	0.28	.000	20,200	14,400	28
4	24.0	20,550	3,090,000	0.32	0.15	0.17	.000	16,800	17,000	37
5	24.0	20,640	3,110,000	0.37	...	...	.000	22,300	12,500	25
6	24.0	20,580	3,100,000	0.44	0.80	0.45	.000	20,400	18,500	30
7	24.0	20,340	3,060,000	0.53	0.26	0.24	.000	9,300	15,100	44
8	24.0	20,310	3,060,000	0.65	0.37	0.16	.000	11,400	11,100	36
9	24.0	20,340	3,060,000	0.89	0.28	0.22	.000	49,400	11,100	85
10	24.0	19,470	2,930,000	1.27	0.92	0.75	.001	34,400	23,300	37
11	24.0	20,340	3,060,000	1.94	0.55	0.55	.006	18,700	20,400	31
12	24.0	19,980	3,010,000	2.20	0.38	0.46	.013	9,550	10,300	30
13	24.0	19,590	2,950,000	2.44	0.31	0.31	.013	8.850	8,200	28
14	24.0	20,460	3,080,000	2.76	0.60	0.42	.017	15,500	6,600	28
15	24.0	20,040	3,020,000	3.00	0.24	0.22	...	10,300	10,100	47
16	24.0	19,860	2,990,000	3.12	0.12	0.16	.007	4,800	4,150	40
17	24.0	19,740	2,970,000	3.26	0.15	0.15	.007	6,450	5,450	26
18	24.0	19,320	2,910,000	3.55	0.08	0.08	.013	7,300	7,000	45
19	23.6	17,560	2 680 000 / 2 640 000	3.90	0.10	0.09	.002	10,800	7,400	28
20	3.5	*2,270	2 380 000 / 340 000	...	0.30	0.07	...	27,300	3,520	37
21	24 0	19,920	3,000,000	0.25	1.75	0.50	.010	25,000	16,300	125
22	24.0	19,860	2,990,000	0.28	0.50	0.50	.017	22,700	11,100	135
23	24.0	20,010	3,010,000	0.32	0.31	0.22	.017	12,600	5,450	67
24	22.0	16,830	2 760 000 / 2 530 000	0.35	0.26	0.17	...	5,600	4,900	88
25	11.0	‡9,020	2 970 000 / 1 360 000	...	0.18	0.11	.020	6,450	5,800	50
26	24.0	20,220	3,050,000	0.21	0.10	0.09	.017	1,920	3,100	72
27	24.0	20,160	3,040,000	0.19	0.09	0.08	.015	3,500	2,670	58
28	24.0	20,160	3,040,000	0.21	0.18	0.13	.010	5,020	2,320	42
29	24.0	20,100	3,030,000	0.23	0.10	0.08	...	3,020	2,800	47
30	24.0	20,160	3,040,000	0.25	0.09	0.08	.010	1,700	1,600	52
31	24.0	20,100	3,030,000	0.27	0.09	0.07	.010	1,520	1,150	74
Totals,	708.1	586,310	88,280,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.8	18,910	2,850,000	.....	0.36	0.25	.008	15,100	10,250	51

NOTES:—Percentage of Bacteria removed, 99.66.
* 14th Scraping; 0.13 feet removed, 626,140 gallons passed (94,280,000 per acre) since 13th Scraping.
‡ 15th " 0.05 " " 78,890 " " (11,870,000 ") " 14th "

RECORD OF SAND FILTER No. 2,

For the Month of July, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
2	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
15	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
17	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
18	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
20	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
21	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
22	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
23	.....	.....	.....	.....	.....	.....	.....	.....	.....	...
24	20.0	11,000	2 020 000 1 680 000	.....	.....	.....	.....	8,260	.....	8,820
25	24.0	13,000	1,980,000	0.11	.....	.....	.....	2,400	.....	1,450
26	22.7	12,200	2 000 000 1 860 000	.....	.....	.....	.....	.....	.....	...
27	18.0	9,500	1 920 000 1 440 000	0.37	0.50	.....	.....	1,300	.....	1,450
28	24.0	12,840	1,960,000	0.54	0.52	.....	.....	3,850	.....	1,100
29	24.0	13,040	1,980,000	0.83	0.57	.....	.....	4,200	.....	1,300
30	24.0	12,460	1,900,000	0.87	0.52	.....	.....	3,250	.....	250
31	24.0	13,010	1,980,000	1.26	0.40	.....	.....	3,900	.....	90
Totals,	180.7	97,050	14,790,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.6	12,130	1,850,000	.....	0.50	.....	.....	3,880	.....	2,066

NOTES:—Percentage of Bacteria removed, 46.8.

The rates of filtration for Filter No. 2 were computed by dividing the "Total Passed" by 0.00656. This figure represents the area of the sand surface, calculated from the preliminary measurements of the basin and gives rates slightly in error. These results, at first about two per cent. too large, gradually changed to about two per cent. too small for the last month of the experiments, due to the fact that the area decreased as sand was removed by scraping.

Where two numbers are given for a certain date in the "Rate" column, the upper one gives the rate of filtration for the actual time in operation. The lower figure gives the rate for twenty-four hours and has been used in computing the total for the month.

RECORD OF SAND FILTER No. 2,

For the Month of August, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	13,080	1,990,000	1.57	0.22	.....	.....	7,250	.....	52
2	24.0	12,400	1,890,000	1.75	0.11	.....	.....	.....	.....	...
3	5.3	710	500 000 / 110 000	1.30	0.09	.....	.....	725	.....	66
4	15.4	* 1,540	358 000 / 230 000	.....	0.08	.....	.....	900	.....	58
5	22.2	7,840	1 300 000 / 1 200 000	0.09	0.08	.....	.....	675	.....	92
6	24.0	14,050	2,140,000	0.19	0.10	.....	.....	750	.....	50
7	24.0	11,920	1,800,000	0.19	.....	.....	.. ...	825	.....	16
8	24.0	14,100	2,150,000	0.31	0.07	.....	.....	625	.....	25
9	24.0	13,700	2,090,000	0.30	0.10	.....	.....	.....	.....	...
10	24.0	13,500	2,060,000	0.37	0.08	.....	.....	625	.....	34
11	24.0	13,460	2,050,000	0.46	0.06	.....	.....	575	.....	12
12	24.0	13,380	2,040,000	0.77	0.80	.....	.....	4,075	.....	59
13	24.0	13,230	2,020,000	1.02	.....	.....	.....	.....	.....	...
14	24.0	12,920	1,970,000	1.35	1.00	.....	.....	4,400	.....	55
15	24.0	13,280	2,020,000	1.66	0.21	.....	.....	1,875	.....	41
16	24.0	18,960	2,890,000	2.25	0.16	.....	.....	.....	.....	...
17	24.0	20,020	3,050,000	2.89	0.15	.....	.....	2,150	.....	44
18	24.0	19,000	2,900,000	3.16	.....	.....	.....	6,250	.....	30
19	24.0	19,390	2,960,000	4.07	0.12	.....	.....	2,075	.....	22
20	22.0	9,730	1 610 000 / 1 480 000	5.59	0.17	.....	.....	6,400	.....	42
21	19.5	‡15,940	2 990 000 / 2 430 000	.....	.....	.....	.....	2,200	.....	88
22	24.0	19,670	3,000,000	0.30	.....	.....	.....	.....	.....	...
23	24.0	19,400	2,960,000	0.38	0.12	.....	.....	1,300	.....	81
24	24.0	19,260	2,930,000	0.36	0.08	.....	.....	500	.....	28
25	24.0	19,350	2,950,000	0.38	.....	.....	.....	1,150	.....	36
26	24.0	19,760	3,010,000	0.40	.....	.....	.....	1,300	.....	38
27	24.0	19,440	2,970,000	0.45	.....	.....	.....	1,325	. ....	18
28	24.0	20,050	3,060,000	0.42	.....	.....	.....	975	.....	12
29	24.0	19,430	2,970,000	0.44	0.08	.....	.....	950	.....	28
30	24.0	19,670	3,000,000	0.32	.....	.....	.....	.....	.....	...
31	24.0	19,610	2,990,000	0.26	0.02	.....	.....	2,362	.....	17
Totals,	708.4	467,790	71,310,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.9	15,090	2,300,000	.....	0.19	.....	.....	2,089	.....	42

NOTES:—Percentage of Bacteria removed, 97.99.
* 1st Scraping; 0.03 feet removed, 123,190 gallons passed (18,780,000 per acre) since beginning.
‡ 2d " 0.04 " " 280,020 " " (35,050,000 ") " 1st Scraping.

RECORD OF SAND FILTER No. 2,

For the Month of September, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,750	3,010,000	0.49	0.02	.....	.....	1,225	.....	7
2	24.0	19,650	3,000,000	0.53	0.05	.....	.....	3,050	.....	16
3	24.0	19,910	3,030,000	0.67	0.09	.....	.....	3,075	.....	47
4	24.0	19,660	3,000,000	0.66	0.04	.....	.....	2,536	.....	11
5	24.0	19,700	3,000,000	0.67	0.04	.....	.....	2,125	.....	7
6	24.0	19,510	2,970,000	0.52	0.04	.....	.....	.....	.....	...
7	24.0	19,730	3,010,000	0.73	.....	.....	.....	1,550	.....	11
8	24 0	19,700	3,000,000	0.79	0.04	.....	.....	2,400	.....	7
9	24.0	19,770	3,010,000	0.89	0.05	.....	.....	.....	.....	26
10	24.0	19,710	3,000,000	1.00	.....	.....	.....	4,538	.....	9
11	24.0	19,680	3,000,000	1.05	0.03	.....	.....	1,613	.....	9
12	24.0	19,770	3,010,000	0.79	.....	.....	.....	625	.....	7
13	24.0	19,680	3,000,000	0.73	0.04	.....	.....	.....	.....	...
14	24.0	19,660	3,000 000	0.50	.....	.....	.....	4,950	.....	7
15	24.0	19,540	2,980,000	0.57	0.03	.....	.....	1,545	.....	4
16	24.0	18,960	2,890,000	0 68	0.04	.....	.....	1,593	.....	5
17	24.0	19,790	3,020 000	0.73	0.04	.....	.....	1,650	.....	27
18	24.0	19,730	3,010,000	1.15	0.07	.....	.....	2,170	.....	27
19	24.0	19,570	2,980,000	1.29	0.05	.....	.....	1,900	.....	18
20	24.0	19,540	2,980,000	1.54	.....	.....	.....	3,225	.....	18
21	24.0	19,680	3,000,000	1.88	0.05	.....	.....	1,225	.....	13
22	24.0	20,010	3,050,000	2.31	0.09	.....	.....	700	.....	7
23	24 0	20,030	3,050,000	2.78	0.04	.....	.....	2,275	.....	19
24	24.0	19,700	3,000,000	3.00	0.05	.....	.....	3,125	.....	41
25	24.0	19,730	3,010,000	3.35	0.05	.....	.....	2,250	.....	44
26	24.0	19,830	3,020,000	3.75	0.05	.....	.....	9,575	.....	10
27	24.0	19,370	2,950,000	3.86	.....	.....	.....	.....	.....	..
28	24.0	19,810	3,020,000	5.07	.....	.....	.....	1,750	.....	7
29	24.0	19,800	3,020,000	5.85	0.06	.....	.....	1,667	.....	12
30	24.0	19,550	2,980,000	6.56	0.07	.....	.....	2,100	.....	25
Totals,	720.0	590,520	90,000,000	.....	.....	.....	.....	.....	.....	....
Av'gs,	24.0	19,680	3,000,000	.....	0.05	.....	.....	2,478	.....	16

NOTE:—Percentage of Bacteria removed, 99.35.

RECORD OF SAND FILTER No. 2,

For the Month of October, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	10,830	1,650,000	7.03	0.08	.....	.....	4,549	.....	10
2	15.4	*12,650	3 000 000 / 1 930 000	.....	0.06	.....	.....	5,525	.....	132
3	24.0	19,700	3,000,000	0.28	0.05	.....	.....	5,625	.....	130
4	24.0	19,930	3,040,000	0.30	.....	.....	.....	.....	.....	...
5	24.0	20,120	3,070,000	0.30	0.05	.....	.....	3,362	.....	21
6	24.0	19,840	3,020,000	0.32	0.05	.....	.....	1,876	.....	19
7	24.0	20,060	3,060,000	0.34	0.04	.....	.....	18,550	.....	10
8	24.0	20,160	3,060,000	0.39	0.04	.....	.....	17,363	.....	18
9	24.0	19,230	2,930,000	0.43	0.03	.....	.....	62,325	.....	15
10	24.0	20,080	3,060,000	0.46	0.03	.....	.....	20,550	.....	13
11	24.0	20,120	3,070,000	0.54	0.03	.....	.....	22,575	.....	...
12	24.0	19,940	3,040,000	0.57	0.03	.....	.....	13,700	.....	12
13	24.0	19,790	3,020,000	0.58	0.03	.....	.....	14,675	.....	13
14	24.0	19,580	2,980,000	0.61	0.03	.....	.....	17,150	.....	21
15	24.0	19,870	3,030,000	0.76	0.03	.....	.....	27,300	.....	16
16	24.0	20,030	3,050,000	0.82	0.03	.....	.....	19,950	.....	33
17	24.0	19,910	3,030,000	0.87	0.03	.....	.....	29,750	.....	15
18	24.0	19,910	3,030,000	0.95	0.03	.....	.....	.....	.....	...
19	24.0	19,700	3,000,000	1.07	.....	...	.....	76,913	.....	18
20	24.0	19,590	2,990,000	1.12	0.03	.....	.....	93,450	.....	19
21	24.0	19 970	3,040,000	1.30	0.03	.....	.....	99,600	.....	24
22	24.0	19,820	3,020,000	1.44	0.03	.....	.....	159,500	.....	22
23	24.0	19,840	3,020,000	1.58	0.03	.....	.....	151,250	.....	26
24	24.0	19,730	3,010,000	1.70	0.03	.....	. ....	196,500	.....	18
25	24.0	19,990	3,050,000	1.80	0.03	.....	.....	.....	.....	...
26	24.0	19,650	3,000,000	1.92	0.03	.....	.....	94,500	.....	25
27	24.0	19,870	3,030,000	2.09	0.03	.....	.....	118,500	.....	34
28	24.0	19,650	2,990,000	2.11	0.03	.....	.....	155,000	.....	25
29	24.0	20,170	3,070,000	2.28	0.02	.....	.....	206,500	.....	26
30	24.0	19,880	3,030,000	2.26	0.02	.....	.....	183,750	.....	124
31	24.0	19,860	3,020,000	2.51	.....	.....	.....	220,300	.....	38
Totals,	735.4	599,470	91,340,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.7	19,340	2,950,000	.....	0.04	.....	.....	72,878	.....	32

NOTES:—Percentage of Bacteria removed, 99.96.
* 3rd Scraping; 0.04 feet removed, 812,930 gallons passed (123,920,000 per acre) since 2nd Scraping.

RECORD OF SAND FILTER No. 2,

For the Month of November, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,840	3,020,000	2.72	0.03	.....	.....	.....	.....	...
2	24.0	20,020	3,050,000	2.95	0.03	.....	.....	111,000	.....	40
3	24.0	19,870	3,030,000	3.01	0.06	.....	.....	.....	.....	173
4	24.0	19,650	3,000,000	3.10	0.04	.....	.....	66,475	.....	202
5	24.0	19,660	3,000,000	3.24	0.04	.....	.....	72,875	.....	49
6	24.0	19,750	3,010,000	3.37	0.05	.....	.....	27,000	.....	36
7	24.0	19,550	2,980,000	3.62	0.06	.....	.....	16,063	.....	150
8	24.0	19,400	2,960,000	3.96	0.04	.....	.....	.....	.....	...
9	24.0	19,740	3,010,000	4.34	0.04	.....	.....	7,850	.....	242
10	24.0	19,400	2,960,000	4.81	0.16	.....	.....	8,550	.....	98
11	24.0	19,360	2,950,000	5.57	0.08	.....	.....	6,375	.....	73
12	24.0	17,740	2,700,000	6.33	0.11	.....	.....	.....	.....	...
13	24.0	11,210	1,710,000	6.98	0.23	.....	.....	6,500	.....	132
14	5.7	* 3,370	2 150 000 / 510 000	.....	.....	.....	.....	8,100	.....	44
15	1.2	600	1 800 000 / 90 000	.....	.....	.....	.....	.....	.....	...
16	0.0	0	0	.....	.....	.....	.....	.....	.....	...
17	0.0	0	0	.....	0.70	.....	.....	21,350	.....	474
18	20.6	15,170	2 590 000 / 2 310 000	0.34	1.00	.....	.....	29,900	.....	1,624
19	24.0	19,410	2,960,000	0.80	0.88	.....	.....	17,950	.....	5,479
20	24.0	19,130	2,920,000	1.76	0.42	.....	.....	21,950	.....	1,393
21	24.0	19,550	2,980,000	2.85	0.26	.....	.....	23,050	.....	1,187
22	24.0	19,600	2,990,000	3.89	0.16	.....	.....	16,800	.....	1,032
23	24.0	17,570	2,680,000	4.94	0.09	.....	.....	21,100	.....	580
24	0.0	‡ 0	0	5.95	0.08	.....	.....	15,150	.....	214
25	23.2	17,200	2 710 000 / 2 620 000	0.22	0.08	.....	.....	12,475	.....	512
26	24.0	19,850	3,020,000	0.39	0.08	.....	.....	10,050	.....	434
27	24.0	19,870	3,030,000	0.37	0.07	.....	.....	8,625	.....	297
28	24.0	19,840	3,020,000	0.40	0.09	.....	.....	17,800	.....	192
29	24.0	19,540	2,980,000	0.56	1.00	.....	.....	.....	.....	...
30	24.0	19,730	3,010,000	1.06	0.50	.....	.....	33,075	.....	511
Totals,	602.7	475,620	72,500,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	20.1	15,850	2,420,000	.....	0.24	.....	.....	25,220	.....	632

NOTES:—Percentage of Bacteria removed, 97.49.
* 4th Scraping; 0.06 feet removed, 837,200 gallons passed (127,580,000 per acre) since 3d Scraping.
‡ 5th " 0.07 " " 111,030 " " (16,930,000 ") " 4th "

RECORD OF SAND FILTER No. 2,

For the Month of December, 1897.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,360	2,950,000	1.77	0.26	.....	.....	36,000	.....	567
2	24.0	19,700	3,000,000	2.24	0.24	.....	.....	23,300	.....	471
3	24.0	19,790	3,020,000	2.76	0.16	.....	.....	17,900	.....	340
4	24 0	19,750	3,010,000	3.15	0.09	.....	.....	17,250	.....	243
5	24.0	19,700	3,000,000	3.57	0.07	.....	.....	11,450	.....	226
6	24.0	19,460	2,970,000	4.12	0.21	.....	.....	.....	.....	...
7	24.0	17,490	2,670,000	4.79	0.36	.....	.....	28,850	.....	144
8	24.0	15,900	2,420,000	6.11	0.33	.....	.....	24,400	.....	125
9	24.0	18,700	2,850,000	5.77	.....	.....	.....	20,050	.....	242
10	24.0	11,500	1,750,000	6.36	0.14	.....	.....	21,100	.....	180
11	9.0	*2,220	800 000 340 000	.....	.....	.....	.....	25,700	.....	474
12	24.0	18,850	2,870,000	0.45	0.10	.....	.....	8,025	.....	350
13	24.0	19,990	3,050,000	0.44	0.09	.....	.....	16,400	.....	224
14	24.0	19,930	3,040,000	0.41	0.09	.....	.....	7,800	.....	145
15	24.0	19,820	3,020,000	0.44	0.09	.....	.....	7,975	.....	90
16	24.0	19,790	3,020,000	0 52	0.38	.....	.....	15,400	.....	132
17	24.0	19,990	3,050,000	0.76	0.50	.....	.....	25,475	.....	231
18	24.0	19,870	3,030,000	1.19	0.50	.....	.....	16,350	.....	211
19	24.0	19,600	2,990,000	1.59	0.33	.....	.....	11,800	.....	54
20	24.0	13,120	2,000,000	1.51	0.19	0.20	.....	13,700	7,350	139
21	24.0	13,150	2,000,000	1.77	0.13	0.18	.....	.....	18,500	...
22	24 0	13,160	2,010,000	1.85	0.12	0.13	.....	.....	.....	...
23	24.0	13,140	2,000,000	1.97	0.40	0.24	.....	13,050	11,650	129
24	24.0	13,400	2,040,000	2.23	0.14	0.17	.....	7,650	10,550	135
25	24.0	13,220	2,020,000	2.41	0.11	0.16	.....	5,025	7,700	144
26	24.0	13,040	1,990,000	2.56	0.10	0.10	.....	.....	.....	...
27	24.0	13,300	2,030,000	2.67	0.07	0.07	.....	2,500	2,350	132
28	24.0	13,240	2,020,000	2.80	0.06	0.06	.....	2,750	4,950	192
29	24.0	13,160	2,010,000	2.99	0.06	0.05	.....	1,900	5,050	234
30	24.0	13,350	2,030,000	3.21	0.06	0.05	.....	4,000	3,950	347
31	24.0	13,220	2,020,000	3.41	0.05	0.04	.....	3,900	4,325	179
Totals,	729.0	499,910	76,220,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.5	16,130	2,460,000	.....	0 19	.....	.....	14,433	.....	225

NOTES:—Percentage of Bacteria removed, 98.44.
* 6th Scraping; 0.09 feet removed, 299,600 gallons passed (45,660,000 per acre) since 5th Scraping.

RECORD OF SAND FILTER No. 2,

For the Month of January, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	12,970	1,980,000	3.52	0.05	0.05	.....	2,000	6,850	210
2	24.0	12,080	1,840,000	3.91	0.05	0.05	.....	4,150	2,900	121
3	4.2	* 2,080	1 880 000 / 320 000	.....	0.03	0.04	.....	.....	.....	...
4	24.0	13,040	1,990,000	0.26	0.04	0.04	.....	1,625	2,425	352
5	24.0	13,300	2,030,000	0.20	0.03	0.03	.....	3,675	4,750	263
6	24.0	13,240	2,020,000	0 23	.....	.....	.....	3,125	5,950	336
7	24.0	13,200	2,010,000	0.25	0.04	0.04	.....	3,950	5,625	286
8	24.0	12,890	1,960,000	0.30	0.22	0.03	.....	8,675	5,600	320
9	24.0	13,370	2,040,000	0:40	0.73	0.13	.....	21,500	11,300	369
10	24.0	12,870	1,960,000	0.66	0.30	0.33	.....	12,550	.....	427
11	24.0	13,400	2,040,000	0.93	0.30	0.21	.....	16,175	16,525	449
12	24.0	13,300	2,030,000	1.25	0.43	0.12	.....	11,375	11,000	441
13	24.0	13,140	2,000,000	1.65	0.57	0.15	.....	16,125	13,450	297
14	24.0	13,360	2,040,000	2.05	0.80	0.38	.....	30,987	19,100	180
15	24.0	13,120	2,000,000	2.42	0.84	0.35	.....	40,350	37,650	159
16	24.0	13,160	2,010,000	2.89	0.48	0 33	.....	45,325	28,925	309
17	24.0	13,260	2,020,000	3.21	0.53	0.30	.....	.....	.....	...
18	24.0	13,060	1,990,000	3.47	0.26	0.22	.015	21,275	32,875	366
19	24.0	13,080	1,990,000	3.72	0.20	0.19	.011	22,700	23,300	242
20	24.0	12,080	1,840,000	3.86	0.12	0.12	.015	11,000	15,650	208
21	5.2	‡ 2,640	1 850 000 / 320 000	4.87	0.16	0.10	.030	12,300	12,650	190
22	24.0	13,110	2,000,000	0.40	0.16	0.13	.023	19,000	13,900	250
23	24.0	13,270	2,020,000	0.47	0.19	0.14	.023	20,450	11,450	417
24	24.0	13,010	1,980,000	0.71	0.30	.....	.023	23,750	17,000	457
25	24.0	13,020	1,990,000	1.36	0.50	.....	.045	26,150	.....	613
26	24.0	13,170	2,010,000	1.93	0.19	.....	.036	12,650	.....	478
27	24.0	13,160	2,010,000	2.56	0.25	0.19	.015	15,000	15,550	236
28	24.0	13,020	1,990,000	2.87	0.22	0.19	.015	14,050	13,950	307
39	24.0	13,090	2,000,000	3.25	0.11	0.12	.015	6,825	10,400	234
30	24.0	12,590	1,920,000	3.62	0 08	0.09	.....	2,600	6,925	160
31	24.0	10,350	1,580,000	3.91	0.09	0.08	.....	.....	.....	...
Totals,	705.4	380,430	58,010,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.8	12,270	1,870,000	.....	0.28	0.15	.022	15,333	13,828	310

NOTES:—Percentage of Bacteria removed, 97.98.
* 7th Scraping; 0.05 feet removed, 341,950 gallons passed (52,150,000 per acre) since 6th Scraping.
‡ 8th " 0.04 " " 226,030 " " (34,450,000 ") " 7th "
* 560 gallons passed before and 1,520 gallons after scraping.
‡ 1,640 " " " " 1,000 " " "

RECORD OF SAND FILTER No. 2,

For the Month of February, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	5.9	*2,640	1 620 000 / 400 000	5.70	0.08	0.07	.011	2,350	5,200	...
2	24.0	13,070	1,990,000	0.23	0.08	0.08	.003	2,250	3,975	317
3	24.0	13,200	2,010,000	0.22	0.09	0.08	.....	2,775	4,050	123
4	24.0	13,190	2,010,000	0.20	0.06	0.08	.006	2,700	3,825	131
5	24.0	13,230	2,020,000	0.26	0.05	0.09	.006	1,575	5,075	112
6	24.0	13,270	2,020,000	0.30	0.05	0.04	.006	1,425	1,925	229
7	24.0	13,400	2,040,000	0.29	.....	.....	.....	.....	.....	...
8	24.0	13,300	2,030,000	0.31	0.04	0 03	.....	1,700	1,775	118
9	24.0	13,230	2,020.000	0.39	0.04	0.03	.....	3,550	3,700	113
10	24.0	13,550	2,060,000	0.48	0.14	0.04	.003	.....	.....	...
11	24.0	13,360	2,040,000	0.55	0.26	0.10	.004	.....	.....	...
12	24 0	13,300	2,030,000	0.65	0.30	0.16	.004	8,025	8,425	177
13	24.0	13,120	2,000,000	0.79	0.48	0.19	.....	17,500	14,300	144
14	24.0	13,400	2,040,000	1.05	0.47	0.20	.....	.....	.....	...
15	24.0	13,420	2,050,000	1.26	0.32	0.19	.015	25,600	33,600	511
16	24.0	13,240	2,020,000	1.35	0.25	0.19	.030	24,150	27,050	617
17	24.0	13,290	2,030,000	1.46	0.19	0.19	.023	23,600	29,000	..
18	24.0	13,440	2,050,000	1.55	0.13	0.14	.015	9,250	12,450	441
19	24.0	13,560	2,070,000	1.58	0.09	0.10	.023	11,025	13,575	415
20	24.0	13,450	2,050,000	1.69	0.08	0.07	.015	7,050	10,700	428
21	24.0	20,000	3,050,000	2.02	.....	.....	.....	.....	.....	...
22	24.0	20,380	3,110,000	2.24	0.16	.....	.015	12,025	.....	307
23	24.0	19,970	3,040,000	2.45	0.15	.....	.015	10,150	.....	321
24	24.0	20,390	3,110,000	2.67	0.13	.....	.010	12,350	.....	162
25	24.0	20,190	3,080,000	2.87	0.11	.....	.....	9,400	.....	256
26	24.0	20,050	3,060,000	2.92	0.08	.....	.015	12,112	.....	314
27	24.0	19,990	3,050,000	3.00	0.07	.....	.015	7,750	.....	272
28	24.0	19,960	3,040,000	3.15	0.05	.....	.....	8,600	.....	...
Totals,	653.9	416,590	63,520,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.4	14,880	2,270,000	.....	0.15	.....	.012	9,430	.....	275

NOTES:—Percentage of Bacteria removed, 97.08.
* 9th Scraping; 0.10 feet removed, 131,430 gallons passed (20,050,000 per acre) since 8th Scraping.

RECORD OF SAND FILTER No. 2,

For the Month of March, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	20,560	3,130,000	3.23	0.04	.....	.010	6,125	.....	201
2	23.6	18,330	2 840 000 / 2 790 000	3.49	0.05	.....	.006	7,650	.....	167
3	10.0	* 6,640	2 420 000 / 1 610 000	.....	.....	.....	.003	7,450	.....	...
4	24.0	20,360	3,100,000	0.36	0.05	.....	.003	4,925	.....	589
5	24.0	20,300	3,090,000	0.31	0.06	.....	.010	4,475	.....	86
6	24.0	20,260	3,090,000	0.30	0.07	.....	.010	5,150	.....	75
7	24.0	20,360	3,100,000	0.33	.....	.....	.....	3,400	.....	...
8	24.0	20,130	3,070,000	0.39	0.04	.....	.006	5,100	.....	81
9	24.0	20,400	3,110,000	0.48	0.05	.....	.006	5,075	.....	105
10	24.0	20,220	3,080,000	0.64	0.05	.....	.010	5,175	.....	217
11	24.0	19,880	3,030,000	0.85	0.06	.....	.....	5,700	.....	130
12	24.0	20,220	3,080,000	1.09	0.05	.....	.003	5,475	.....	157
13	24.0	20,040	3,050,000	1.24	0.05	.....	.015	6,525	.....	107
14	24.0	19,960	3,040,000	1.44	0.08	.....	.....	.....	.....	...
15	24.0	19,800	3,020,000	1.54	0.12	.....	.015	12,025	.....	109
16	24.0	20,160	3,070,000	1.65	0.12	.....	.015	14,175	.....	203
17	24.0	19,910	3,030,000	1.69	0.11	.....	.010	12,400	.....	272
18	24.0	20,090	3,060,000	1.77	0.10	.....	.015	7,350	.....	252
19	24.0	20,510	3,130,000	1.94	0.09	.....	.015	8,600	.....	103
20	24.0	19,790	3,020,000	2.09	0.08	.....	.006	9,900	.....	165
21	24.0	19,110	2,910,000	2.52	0.49	.....	.010	.....	.....	...
22	24.0	19,720	3,010,000	3.86	0.90	.....	.022	.....	.....	...
23	15.2	† 8,900	2 150 000 / 1 360 000	.....	1.00	.....	.015	56,000	.....	1,120
24	24.0	19,880	3,030,000	0.49	2.38	.....	.030	55,483	.....	1,391
25	24.0	19,800	3,020,000	1.32	0.90	.....	.099	23,267	.....	1,192
26	24.0	19,650	2,990,000	2.34	0.41	.....	.055	14,400	.....	479
27	24.0	19,270	2,940,000	3.31	0.20	.....	.032	7,000	.....	227
28	21.6	14,900	2 520 000 / 2 270 000	4.36	0.17	.....	.....	4,800	.....	205
29	9.0	‡ 6,360	2 590 000 / 970 000	.....	0.20	.....	.....	4,750	.....	...
30	24.0	20,200	3,080,000	0.30	0.29	.....	.015	9,967	.....	169
31	24.0	20,140	3,070,000	0.33	0.50	.....	.030	16,583	.....	491
Totals,	703.4	575,850	87,750,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.7	18,580	2,830,000	.....	0.30	.....	.018	11,747	.....	332

NOTES:—Percentage of Bacteria removed, 97.11.
* 10th Scraping; 0.06 feet removed, 452,840 gallons passed (69,040,000 per acre) since 9th Scraping.
† 11th " 0.06 " " 389,830 " " (59,400,000 ") " 10th "
‡ 12th " 0.13 " " 100,430 " " (15,310,000 ") " 11th "
† 1,970 gallons passed before and 6,930 gallons after scraping.

RECORD OF SAND FILTER No. 2,

For the Month of April, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,850	3,020,000	0.43	0.18	.....	.036	8,500	.....	300
2	24.0	19,720	3,010,000	0.60	0.17	.....	.022	5,375	.....	153
3	24.0	20,030	3,050,000	0.79	0.13	.....	.015	5,287	.....	153
4	24.0	20,080	3,060,000	1.02	0.11	.....	.....	3,667	.....	127
5	24.0	20,020	3,050,000	1.28	0.08	.....	.015	2,937	.....	116
6	24.0	20,270	3,090,000	1.59	0.07	.....	.006	2,512	.....	80
7	24.0	20,070	3,060,000	1.94	0.07	.....	.006	2,562	.....	89
8	24.0	20,110	3,070,000	2.25	0.08	.....	.003	1,725	.....	91
9	24.0	19,510	2,980,000	2.74	0.07	.....	.003	2,112	.....	75
10	24.0	19,970	3,040,000	3.26	0.05	.....	.001	2,925	.....	82
11	24.0	20,200	3,080,000	3.64	0.04	.....	.....	2,917	.....	80
12	24.0	17,130	2,610,000	3.97	0.04	.....	.001	3,037	.....	81
13	10.2	* 7,830	2 800 000 / 1 190 000	.....	0.04	.....	.001	3,575	.....	77
14	24.0	20,170	3,080,000	0.30	0.04	.....	.001	2,537	.....	84
15	24.0	20 290	3,090,000	0.35	0.04	.....	.001	2,980	.....	88
16	24.0	20,420	3,110,000	0.27	0.04	.....	.001	2,612	.....	61
17	24.0	20,350	3,100,000	0 27	0.03	.....	.003	1,525	.....	104
18	24.0	20,340	3,100,000	0 25	0.06	.....	.....	2,317	.....	213
19	24.0	20,260	3,090,000	0.32	0.05	.....	.....	2,525	.....	64
20	24.0	20,580	3,140,000	0.35	0.04	.....	.001	2,750	.....	58
21	24.0	20,690	3,150,000	0.37	0.06	.....	.001	2,162	.....	46
22	24.0	20,570	3,140,000	0.42	0.05	.....	.001	1,537	.....	37
23	24.0	19,820	3,020,000	0.46	0.04	.....	.001	1,425	.....	29
24	24.0	20,050	3,060,000	0.50	0.04	.....	.001	2.410	.....	67
25	24.0	19,960	3,040,000	0.53	0.06	.....	.....	7,350	.....	90
26	24.0	19,890	3,030,000	0.55	0.20	.....	.001	16,000	.....	46
27	24.0	20,260	3,090,000	0.81	0.23	.....	.001	18,912	.....	77
28	24.0	20,370	3,110,000	0.96	0.21	.....	.002	17,725	.....	78
29	24.0	20,030	3,050,000	1.14	0.12	.....	.004	10,587	.....	48
30	24.0	20,120	3,070,000	1.30	0.09	.....	.003	7,812	.....	43
Totals,	706.2	588,960	89,780,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.5	19,630	2,990,000	.....	0.08	.....	.005	5,010	.....	91

NOTES:—Percentage of Bacteria removed, 98.18.
* 12th Scraping; 0.07 feet removed, 283,930 gallons passed (43,830,000 per acre) since 12th Scraping.
* 270 gallons passed before. and 7,560 gallons after scraping.

RECORD OF SAND FILTER No. 2,

For the Month of May, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	19,970	3,040,000	1.40	...	.....	.003	5,490	.....	45
2	24.0	19,890	3,030,000	1.50	0.05	.....	...	4,380	.....	106
3	24.0	19,740	3,010,000	1.60	0.03	.....	.001	3,120	.....	50
4	24.0	20,120	3,070,000	1.80	0.04	.....	.001	4,090	.....	47
5	24.0	20,180	3,080,000	1.96	0.05	.....	.000	4,020	.....	145
6	24.0	20,450	3,120,000	2.12	0.04	.....	.000	3,350	.....	30
7	24.0	20,030	3,050,000	2.28	0.04	.....	.005	3,060	.....	32
8	24.0	19,720	3,010,000	2.51	0.05	.....	.003	4,720	.....	23
9	24.0	19,210	2,930,000	2.91	0.17	.....	...	13,500	.....	35
10	24.0	13,820	2,100,000	4.03	0.28	.....	.006	19,400	.....	41
11	12.1	* 8,500	$\frac{2\ 550\ 000}{1\ 800\ 000}$	...	0.10	.....	.010	8,100	.....	68
12	24.0	20,000	3,050,000	0.24	0.05	.....	.009	4,960	.....	75
13	24.0	20,020	3,050,000	0.22	0.07	.....	.009	4,310	.....	63
14	24.0	20,020	3,050,000	0.22	0.04	.....	.009	4,510	.....	63
15	24.0	20,030	3,050,000	0.20	0.06	.....	.009	7,400	.....	93
16	24.0	20,090	3,060,000	0.21	0.10	.....	...	7,050	.....	165
17	24.0	20,050	3,060,000	0.23	0 20	.....	.007	33,600	.....	180
18	24.0	20,020	3,050,000	0.34	1.20	.....	.019	55,000	.....	195
19	24.0	19,790	3,020,000	0.59	0.40	.....	.022	17,000	.....	195
20	24 0	20,440	3,120,000	0.69	0.18	.....	.028	12,500	.....	260
21	24.0	19,450	2,970,000	0.82	0.18	.....	.018	12,700	.....	230
22	24.0	19,780	3,010,000	1.04	0.55	.....	.018	22,800	.....	325
23	24.0	20,080	3,060,000	1.37	0.40	.....	.020	13,200	.....	70
24	24.0	19,940	3,040,000	1.51	0.15	.....	.028	13,900	.....	71
25	24.0	19,680	3,000,000	1.76	0.50	.....	.022	19,500	.....	69
26	24.0	19,900	3,030,000	2.05	0.31	.....	.020	12,500	.....	67
27	24.0	20,090	3,060,000	2.30	0.19	.....	.015	6,400	.....	59
28	24.0	19,780	3,010,000	2.49	0.11	.....	.018	3,840	.....	54
29	24.0	19,820	3,020,000	2.61	0.09	.....	.015	3,410	.....	98
30	24.0	19,930	3,040,000	3.06	0.10	.....	.015	4,070	.....	60
31	24.0	20,060	3,060,000	3.01	0.05	.....	.013	1,500	.....	49
Totals,	732.1	600,600	91,550,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.6	19,370	2,950,000	.....	0.19	.....	0.12	10,800	.....	99

NOTES:—Percentage of Bacteria removed, 99.03.
*14th Scraping; 0.07 feet removed, 545,360 gallons passed (83,140,000 per acre) since 13th Scraping.
*500 gallons passed before and 8,000 gallons after scraping.

RECORD OF SAND FILTER No. 2,

For the Month of June, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	20,350	3,100,000	2.94	0.07	.....	.015	1,960	.....	44
2	24.0	20,200	3,080,000	2.85	0.04	..	.010	1,700	.....	37
3	24.0	19,540	2,980,000	3.24	0.06	.....	.015	1,420	.....	58
4	24.0	16,190	2,470,000	3.90	0.04	.....	.012	3,020	.....	66
5	5.9	* 2,700	1 650 000 / 410 000	.....	0.03	.....	.012	2,300	.....	83
6	24.0	20,000	3,050,000	0.30	0.02	.....	.....	3,540	.....	105
7	24.0	20,150	3,070,000	0.23	0.02	.....	.009	3,460	.....	120
8	24.0	20,250	3,090,000	0.20	0.02	.....	.009	12,000	.....	190
9	24.0	19,880	3,030,000	0.18	0.02	.....	.008	23,400	.....	90
10	24.0	19,890	3,030,000	0.19	0 02	.....	.007	17,400	.....	68
11	24.0	19,950	3,040,000	0.18	0.02	.....	.....	28,300	.....	68
12	24.0	19,880	3,030,000	0.16	0.02	.....	.005	19,500	.....	80
13	24.0	20,380	3,110,000	0.17	0.02	.....	.....	12,400	.....	73
14	24.0	20,150	3,070,000	0.15	0.03	.....	.005	21,200	.....	52
15	24.0	19,720	3,010,000	0.29	0.70	.....	.002	27,900	.....	57
16	24.0	19,370	2,950,000	0.55	0.80	.....	.007	16,500	.....	104
17	24.0	20,060	3,060,000	0.82	0.42	.....	.010	7 650	.....	68
18	24.0	19,460	2,970,000	1.01	0.21	.....	.010	4,250	.....	55
19	24.0	20,020	3,050,000	1.38	0.15	.....	.007	6,150	.....	45
20	24.0	19,700	3,000,000	1.90	0.40	.....	.013	28,900	.....	27
21	24.0	17,060	2,600,000	3.23	0.65	.....	.022	25,100	.....	38
22	8.9	‡ 6,500	‡ 670 000 / 990 000	.....	0.70	.....	.018	15,600	.....	93
23	24.0	20,020	3,050,000	0.25	0.42	.....	.025	5,950	.....	100
24	24.0	20,060	3,060,000	0.24	0.23	.....	.025	3 500	.....	73
25	24.0	20,220	3,080,000	0.20	0.12	.....	.025	2,700	.....	58
26	24.0	20.000	3.050,000	0.21	0.12	.....	.013	4,980	.....	58
27	24.0	20,080	3,060,000	0.20	0.11	.....	.015	.....	.....	63
28	24.0	19.940	3,040,000	0.23	0.07	.....	.013	3 770	.....	76
29	24.0	19,940	3,040 000	0.24	0.07	.....	.012	6,250	.....	66
30	24.0	19,920	3,030,000	0.30	0.06	.....	.010	11,200	.....	60
Totals,	686.8	561,580	85,600,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	22.9	18,720	2,850,000	.....	0.19	.....	.012	11,100	.....	72

NOTES:—Percentage of Bacteria removed, 99.35.
* 15th Scraping; 0.10 feet removed, 484.950 gallons passed (73,920,000 per acre) since 14th Scraping.
‡ 16th " 0.11 " " 317,620 " " (48,420,000 ") " 15th "
* 1,700 gallons passed before and 1,000 gallons after scraping.
‡ 700 " " " " 5,800 " " "

RECORD OF SAND FILTER No. 2,

For the Month of July, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	33,390	5,090,000	0.60	0.29	0.07	.002	6,000	4,750	47
2	24.0	33,090	5,040,000	0.78	0.22	0.12	.010	5,700	3,770	57
3	24.0	32,480	4,950,000	0.99	0.17	0.11	.012	5,250	2,700	46
4	24.0	33,600	5,120,000	1.30	0.11	0.09	.....	4,150	4,600	59
5	24.0	33,300	5,080,000	1.62	0.09	0.09	.....	3,150	3,000	76
6	24.0	32,850	5,010,000	2.07	0 05	0 06	.....	6,850	1,370	110
7	24.0	32,800	5,000,000	2.52	0.05	0.06	.007	6,350	4,350	55
8	24.0	33,500	5,110,000	3.07	0.08	0.09	.007	5,650	4,200	50
9	20.6	24,000	4 260 000 3 660 000	3.75	0.05	0.04	.005	10,350	11,900	65
10	13.6	*18,130	4 870 000 2 760 000	.....	0.05	0.03	.....	8,100	6,100	500
11	24.0	33,580	5,120,000	0.42	0.04	0.04	.....	10,250	.....	295
12	24.0	33,980	5,180,000	0.37	0.04	0.03	.002	3,850	2,000	104
13	24.0	33,830	5,160,000	0.35	0.05	0.04	.001	19,800	6,400	65
14	24.0	33,900	5,170,000	0.31	0.04	0.04	.001	40,500	14,900	119
15	24 0	34,000	5,180,000	0.32	0.03	0.03	.001	40,200	27,900	166
16	24.0	34,000	5,180,000	0.32	0.08	0.06	.001	42,600	29,000	140
17	24.0	33 650	5,130,000	0.33	0.80	0.14	.007	41,000	38,800	99
18	24.0	33,900	5,170,000	0.37	0.10	0.15	.001	35,200	26,400	66
19	24.0	33,700	5,140,000	0.39	0.06	0.13	.000	14,400	18,100	57
20	24.0	33,480	5,100,000	0.42	0.07	0.13	.003	22,600	12,900	42
21	24.0	33,280	5,070,000	0.45	0.19	0.09	.002	24,500	15,200	37
22	24.0	33,750	5,140,000	0.53	0.11	0.10	.001	20,800	14,400	51
23	24.0	33,570	5,120,000	0.59	0.05	0.06	.000	15,200	20,200	62
24	24.0	33,100	5,050,000	0.64	0.03	0.05	.000	8,050	12,200	56
25	24.0	32,850	5,010,000	0.89	0.06	0.06	.....	14,600	11,700	48
26	24.0	33,550	5,110,000	0.99	0.06	0.06	.001	8,750	11,500	62
27	24.0	33,100	5,050,000	1.34	0.09	0.12	.000	16,500	9,900	49
28	24.0	33,400	5,090,000	1.60	0.06	0.06	.000	24,500	28,200	39
29	24.0	33,000	5,030,000	1.84	0.05	0.05	.000	18,500	13,700	43
30	24 0	32,850	5,010,000	2.19	0.05	0.04	.005	17,700	15,600	68
31	24.0	32,600	4,970,000	2.54	0.06	0.06	.000	20,100	14,500	35
Totals,	730.2	1,010,210	154,000,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.6	32,590	4,970,000	.....	0.11	0.07	.002	16,800	13,000	89

NOTES:—Percentage of Bacteria removed, 99.47.
* 17th Scraping; 0.06 feet removed, 454,990 gallons passed (69,350,000 per acre) since 16th Scraping.

RECORD OF SAND FILTER No. 2,

For the Month of August, 1898.

Date. 24 Hours Ending 9.00 A.M.	Hours in Operation.	Quantity in Gallons.		Loss of Head in Feet.	Turbidity.			Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.		Gate Chamber.	Settling Basin.	Effluent.	Gate Chamber.	Settling Basin.	Effluent.
1	24.0	32,100	4,890,000	3.20	0.42	0.14	...	48,200	26,100	35
2	24.0	24,800	3,780,000	4.13	0.70	0.50	.000	27,500	28,700	55
3	12.4	*15,600	4 610 000 / 2 880 000	...	0.35	0.28	...	20,200	14,400	96
4	24.0	33,700	5,140,000	0.37	0.15	0.17	.000	16,800	17,000	145
5	24.0	33,800	5,150,000	0.34	...	...	.000	22,300	12,500	60
6	24.0	33,900	5,170,000	0.34	0.80	0.45	.001	20,400	18,500	49
7	24.0	33,700	5,140,000	0.37	0.26	0.24	.000	9,300	15,100	37
8	24.0	33,600	5,120,000	0.42	0.37	0.16	.000	11,400	11,100	60
9	24.0	33,500	5,110,000	0.52	0.28	0.22	.000	49,400	11,100	44
10	24.0	33,300	5,080,000	0.65	0.92	0.75	.004	34,400	23,300	77
11	24.0	33,500	5,110,000	0.86	0.55	0.55	.025	18,700	20,400	130
12	24.0	33,000	5,030,000	1.04	0.38	0.46	.025	9,550	10,300	59
13	24.0	33,500	5,110,000	1.26	0.31	0.31	.025	8,850	8,200	69
14	24.0	33,000	5,030,000	1.51	0.60	0.42	.027	15,500	6,600	48
15	24.0	33,700	5,140,000	1.80	0.24	0.22	...	10,300	10,100	57
16	24.0	33,600	5,120,000	1.96	0.12	0.16	.023	4,800	4,150	50
17	24.0	33,500	5,110,000	2.16	0.15	0.15	.020	6,450	5,450	48
18	24.0	33,000	5,030,000	2.45	0.08	0.08	.017	7,300	7,000	58
19	24.0	33,300	5,080,000	2.74	0.10	0.09	.011	10,800	7,400	67
20	23.5	30,900	4 810 000 / 4 710 000	2.99	0.30	0.07	.010	27,300	3,520	77
21	23.7	26,800	4 140 000 / 4 090 000	3.95	1.75	0.50	.010	25,000	16,300	54
22	9.5	‡12,700	4 990 000 / 1 940 000	...	0.50	0.50	...	22,700	11,100	225
23	24.0	33,500	5,110,000	0.48	0.31	0.22	.075	12,600	5,450	240
24	24.0	33,400	5,090,000	0.43	0.26	0.17	.055	5,600	4,900	125
25	24.0	33,400	5,090,000	0.45	0.18	0.11	.025	6,450	5,800	110
26	24.0	33,300	5,080,000	0.43	0.10	0.09	.020	1,920	3,100	77
27	24.0	33,200	5,060,000	0.45	0.09	0.08	.017	3,500	2,670	85
28	24.0	33,000	5,030,000	0.53	0.18	0.13	.017	5,020	2,320	78
29	24.0	33,700	5,140,000	0.60	0.10	0.08	...	3,020	2,800	85
30	24 0	33,700	5,140,000	0.69	0.09	0.08	.015	1,700	1,600	74
31	24.0	33,600	5,120,000	0.76	0.09	0.07	.015	1,520	1,150	69
Totals,	717.1	979,300	149,320,000	.....	.....	.....	.....	.....	.....	...
Av'gs,	23.1	31,600	4,820,000	.....	0.36	0.25	.017	15,100	10,250	82

NOTES:—Percentage of Bacteria removed, 99.46.
* 18th Scraping; 0.07 feet removed. 778,950 gallons passed (118,740,000 per acre) since 17th Scraping.
‡ 19th " 0.12 " " 608,050 " " (92,720,000 ") " 18th "
* 850 gallons passed before and 14,750 gallons after scraping.

CHAPTER III.

WARREN FILTER EXPERIMENTS.

Description.

A complete sectional plan and elevation of the Warren Filter used in these experiments will be found on Plates No. 15 and No. 16, opposite page 156. In the description many things will be mentioned, which are common to both the Warren and Jewell Filter Systems; and, in order to save repetition, they will be described in sufficient detail here and simply noted in Chapter IV.*

The water was supplied from the six-inch main in the center of the building, through a four-inch pipe, which entered at one end of the settling basin; the coagulant was also introduced at this same point. After leaving the settling basin, the water passed to the filter through an eight-inch pipe under the filter tank, and up through a central well over the filter bed. After passing down through the filter bed, the water was collected in troughs underneath, which were covered with perforated screens. From these troughs the water flowed to an iron stand pipe outside the filter, in which was placed a so-called automatic weir. From the weir the water passed out through a six-inch meter into the effluent tank under the floor. Wash water was pumped to the filter, when required, through a four-inch line leading to the effluent pipe, and, after passing up through the sand, overflowed down through angular gutters and out through a waste pipe at the opposite side of the filter.

Settling Basin.

The settling basin was an eliptical wooden tank, having an area of 176 square feet and a capacity of 13,200 gallons; or equal to the flow for forty minutes with the filter running at the rate of 120,000,000 gallons per acre daily. The basin was divided into four parts by baffle walls, and the distance from the inlet to the outlet, along the center line of flow, was about 36 feet. Displacement was not complete, however and changes in the character of the applied water were quite often noticed at the outlet much sooner than the time above mentioned. The outlet consisted of a vertical box, two and one-half square feet in area and extending from the bottom to within two feet of the top of the basin. All water passed down through this box to the exit pipe. In the bottom, near the outlet, there was a flap valve for the removal of mud and sediment.

The entering water passed through a four-inch meter; then through a butterfly valve, connected with a float, which by regulating the supply, controlled the water level in the basin and filter. The water then passed through an eight-blade propeller wheel, six inches in diameter. This propeller revolved with a speed in proportion to the rate of flow of the

*The relation of the Warren Filter System to other apparatus is shown upon Plate No. 13, opposite Page 116.

entering water. Connection was made through a vertical shaft with bevelled gears, to operate a modified form of tympanum, or pump, made of vulcanized rubber.

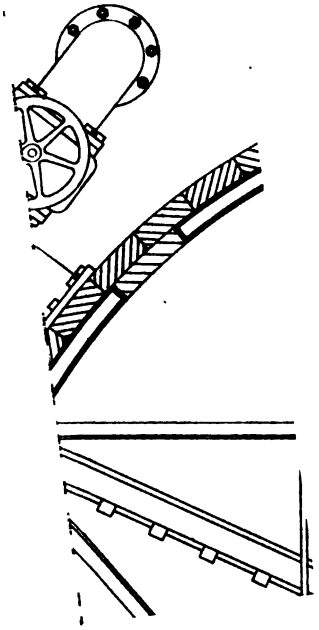
Coagulant.

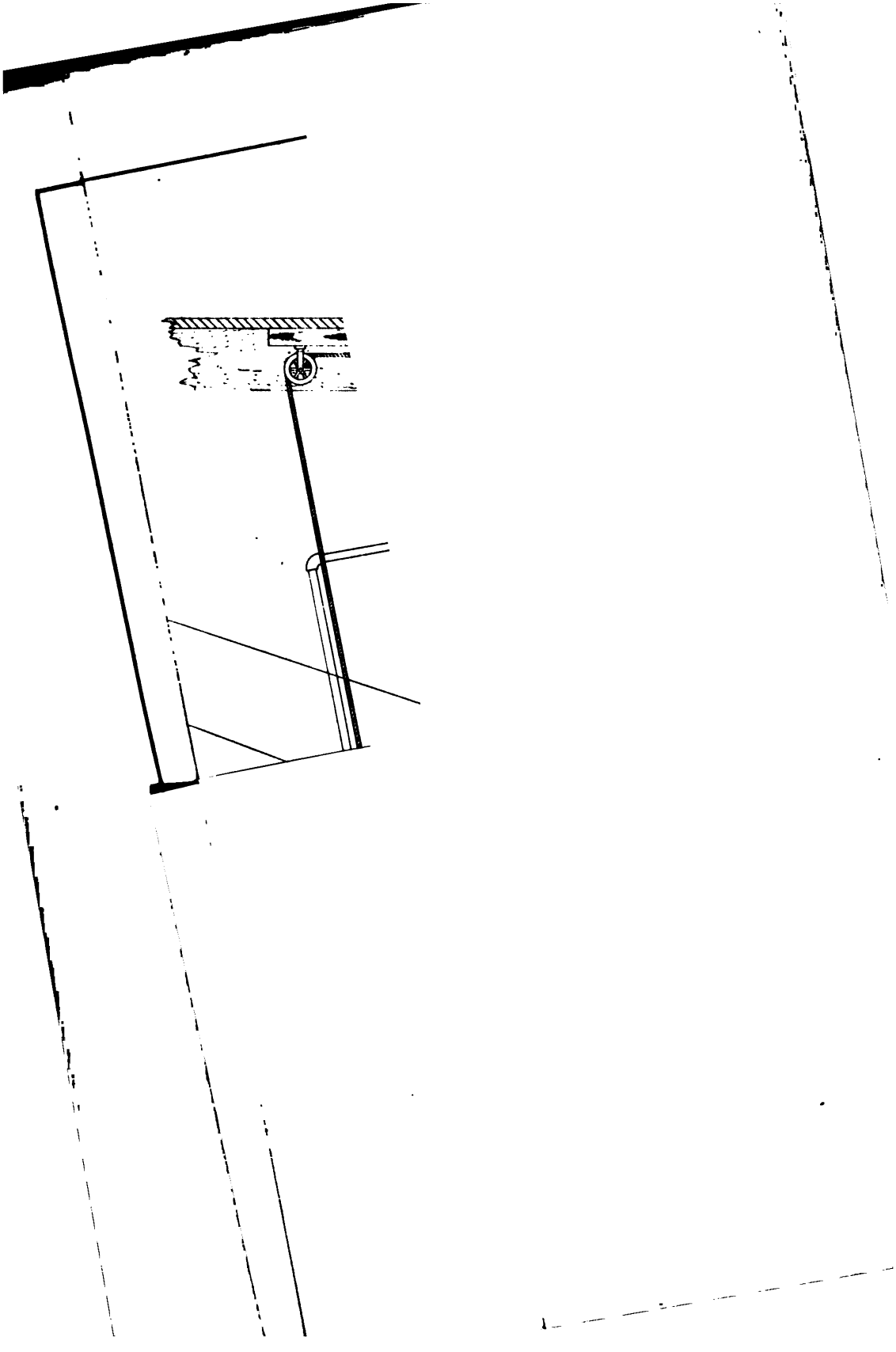
The inner end of each arm of the pump was connected to one of a series of six tubes, placed in the hub and parallel to the shaft. The inside diameter of each arm was half an inch. This pump revolved in a tank, which was kept full of the solution of sulphate of alumina, and each arm, in turn, was filled with the solution. Later in the revolution, this flowed down into the hub and out into a lead cup on the side of the tank. From this cup a lead pipe carried the solution down into the settling basin. The quantity of the coagulant was varied, either by changing the strength of the solution, or by inserting stoppers in some of the arms of the pump. The sulphate of alumina was dissolved in water in tubs, holding 390 gallons each, placed on top of the settling basin, and the solution was always thoroughly mixed before being used. These tubs were connected by brass piping with the tank in which the pump was placed, and the solution was allowed to flow from one tank at a time.

The elevation of the solution in the pump tank was kept as constant as possible by rubber float valves. It was found, however, that this method was not entirely satisfactory, as the rubber valves frequently became clogged. When a new solution was first used, the higher elevation of the solution in the pump tank, due to the pressure from a full tub, caused very much more coagulant to be added to the applied water than when the solution in the upper tub had nearly run out. To offset this trouble, the valve from the upper tub was opened a little only at the beginning, and this opening was gradually increased as the tub became emptied. Even in this way, the application of the coagulant solution was not constant; the effect of which will be shown by the tables presented under the discussion of, "*Variations in the Rate of Filtration and in the Application of Coagulant.*" There was a scale upon each coagulant tub, graduated in percentages of the full capacity. The records show the amount of coagulant dissolved and the percentage of a full tub remaining unused at various times, from which the exact amount used during any given period was calculated.

Filter.

The filter had an effective sand area of 118 square feet and was composed of a circular wooden tank resting upon timbers, which were placed upon the floor of the buiding. On the bottom of the inside of the tank there were placed radial iron troughs, set in concrete, which served as a support for a brass strainer floor, and also as collectors for the filtered





water. Under the bottom of the tank and connected directly with the eight-inch inlet pipe, there was a central well, 1.50 feet in diameter inside, which extended up through the floor 0.77 foot above the sand surface. Connected with this central well and between the collecting troughs, there were ten two-inch horizontal pipes, which connected with iron gutters, or vertical troughs, placed around the circumference of the filter inside the staves. The inlet water to the filter was distributed over the sand surface from the central well, and from the circumferential gutters.

The sand used was crushed quartz, which was angular at first, but the sharp edges became rounded after some months of use. The effective size was 0.63 m. m.; and the uniformity coefficient, 1. 1. The sand, which was 2.3 feet deep, rested directly upon the brass strainers, or screens, which were composed of perforated plates fastened to the radial iron troughs. There were ten of these radial plates and each had about 292,900 holes, each hole being 0.024 inch in diameter. There were twenty holes to each inch, in a radial direction, and ten in a line at right angles to this. The whole exit system, therefore, comprised a total area of 9.2 square feet. The flow from one-quarter of the holes was obstructed, as they were directly over the ribs of the troughs, and the net exit area was estimated to be 7.1 square feet. The total exit area of the radial troughs was 0.87 square foot. In addition to this last area, there were small screens, each two inches in diameter, placed around the central well; the total area of which was 0.02 square foot. From the troughs, the water drained into a central annular compartment, of 1.13 square feet in area, from which the water passed, through an eight-inch pipe, to the chamber of the automatic weir. The water rose to a level in this chamber, dependent upon the loss of head, caused by the clogging of the filter, and passed down through an inside center pipe and out to a six-inch meter, which registered all the water passing through the filter. Outside of the pipe, placed inside of the weir chamber, there was a sliding pipe, which was attached at the top to a copper float; thereby maintaining an approximately constant head upon the orifice in the pipe. By this means, it was intended to deliver a constant quantity, whatever the loss of head. In fact, however, the quantities filtered were somewhat greater shortly after washing, than before. This is explained at a greater length under the head of "*Variations in the Rate of Filtration, and in the Application of Coagulant.*

Washing.

Filtered water was furnished to this filter for washing purposes, and also to the Jewell Filter, by two duplex steam pumps, size 12 x 7 x 18. These pumps drew water from the large tank, under the building, which received the effluents from the two filters. The wash water passed through a four-inch meter and then entered the filter through the effluent pipe,

passing up through the perforated screens and sand in the opposite direction to that of the current of water when filtering. As the dirty water flooded above the sand, it overflowed down through the central well and annular gutters, from which it passed out through the eight-inch pipe, by which the settled water entered, and into the sewer.

Agitator.

The agitator consisted of two horizontal arms, connected to a central vertical shaft, upon each of which were nine teeth, each tooth being three feet long. When the agitator was placed in the lowest position, the bottom of the rakes just cleared the strainer floor by 0.14 foot. The agitator was raised and lowered by means of a hydraulic lift, supported by I beams, placed upon the top of the filter. Power was given to this lift from the water supply system through a three-way cock, placed upon the side of the filter. These I beams also supported the proper pulley and gears which transmitted power to the rakes. Power was supplied to the pulley by a belt from the main shafting. Power to the shafting was given by a small 6-inch x 8½-inch engine, placed upon the floor, which was supplied with steam at 100 pounds pressure, and which ran at 300 revolutions per minute. The rake system made about three revolutions per minute.

General.

When the Warren Filter and settling basin were first filled with water they leaked very badly, and, a sewer trench under the building being open at the time, the sills of the building settled in places under the filter. The settlement amounted to about two inches on one side, and, in order that the operations of the filter should not be in any way disturbed, the floor timbers were levelled up.

It was found necessary to allow an abundance of air to enter the top of the central pipe of the automatic weir, to prevent a vacuum being formed and thus cause the float and orifice to drop, causing too much water to flow. The entrance of the air, however, caused serious overregistration of the meter upon the effluent pipe; the error occasioned in this way reaching thirteen per cent. After a trial of various devices, vents were arranged which reduced this error to four per cent.

Before the reducing pressure valve was placed upon the inlet water system, upon February 17, 1898, many of the rubber discs to the four-inch inlet meters were broken; also many of those used in the wash meters were broken. Later, brass discs were used in both places and no further trouble of this kind was experienced. The service upon the wash lines was quite severe, the meters being placed at a short distance from the pumps, and frequently the pins and rollers were broken. The Pittsburgh Meter Company deserves special mention for its zealous interest and efforts in meeting these difficult conditions.

Operations.

In addition to the records taken to determine the amount of inlet, wash, and effluent waters, and the amount of coagulant applied, it was provided in the record books that the exact time of the various items of operation should be entered and the loss of head observed at frequent intervals. The latter, which was allowed to reach a limit of five feet before washing, was determined by the difference between the heights of water in two glass gage tubes; one of which was connected with the water on the surface of the filter and the other with the effluent pipe before the automatic weir. The records taken at 9.00 A. M. served as a basis of the calculations of the day's work, but all the observations were also made at 3.00 P. M., 9.00 P. M., and 3.00 A. M. Special records, taken at times of washing, served as a basis of calculation in regard to this important detail.

There were frequent interruptions in the operations during the first two weeks, in fact, it was January 29, 1897, before the filter was run during the night. Delays in the operations are noted upon the monthly record sheets in the proper places.

COMPOSITION OF COAGULANT.

The sulphate of alumina used during the experiments, with both the Warren and Jewell Filters, had the following composition, as determined from frequent analyses.

TABLE A.

Analysis of Sulphate of Alumina Used in the Experiments.

Calendar Date of Collection, 1898.		Parts by Weight.			
		Aluminum Oxide, Soluble in Water.	Iron Oxide.	Sulphuric Acid.	Insoluble in Water.
January	22	16.96	0.00	38.95	0.12
"	31	16.96	0.00	38.51	0.36
February	..	17.32	0.00	39.18	0.13
March	30	16.70	0.00	37.84	0.42
April	..	16.68	0.00	38.85	0.10
"	..	17.00	0.00	37.90	0.25
"	..	16.52	0.00	35.49	0.15
May	3	16.88	0.00	37.96	0.30
"	23	17.04	0.00	37.67	0.25
"	..	17.22	0.00	38.00	0.20
"	30	16.94	0.00	39.30	0.26
June	9	17.28	0.00	39.70	0.18
"	20	17.40	0.00	38.54	0.14
July	2	17.90	0.00	39.60	0.35
"	13	19.04	0.00	39.29	0.13
"	26	18.84	0.00	39.56	0.20
August	4	17.64	0.00	39.09	0.26
"	12	15.76	0.00	40.59	0.37
"	20	15.92	0.00	38.57	0.40
Averages,		17.18	0.00	38.66	0.24

VARIATIONS IN THE RATE OF FILTRATION AND IN THE APPLICATION OF COAGULANT.

In carrying on the experiments it was soon noticed that the quantity of water filtered was not always the same; that it was frequently greatest directly after a washing and gradually diminished when the filter became clogged, as the time for another washing approached. Tests were conducted occasionally with the special object of ascertaining the facts, as to whether or not the filter was wholly automatic in action, and as to whether the weir regulated accurately the quantities of water filtered. The information in Table B shows the results of one of these tests, which is taken as representing average conditions.

It may be noted here that until July 13, 1898, a 300,000 gallon orifice ring was used in the weir. For the first few months the quantity of effluent was maintained at about this quantity. During the month of June, however, there was a noticeable decrease in the quantity, and upon July 13, a 350,000 gallon ring was placed in the weir, which remained until the close of the experiments.

It was also noticed that the effluent from this filter frequently became turbid, when the character of the applied water had not changed, and while the coagulant solution remained of the same strength. Regarding this, it was noticed that, when a new solution of sulphate of alumina was first used, greater quantities were administered to the water in the settling basin, due to the great head from the pipe leading to the pump tank. Tests were also conducted, sometimes in connection with those previously mentioned, to furnish information about this feature.

The results of representative tests are given; in Table B, compared with the quantity of water filtered, and in Tables C, D, and E, compared with the estimated amount of sulphate of alumina used, computed from the decrease in alkalinity. Table B also shows the number of bacteria in the samples, collected many times during the test.

TABLE B.

Special Test with the Warren Filter.

Variations in the Rate of Filtration and in the Application of Coagulant, For the 24 Hours Ending 9.00 A. M., April 15, 1898.

For the 30 Minutes Ending.	Effluent Quantity, Gallons.	Sulphate of Alumina Used.		Bacteria Per Cubic Centimeter.	
		Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.
9.30 A. M.	7,890	0.65	0.58	3,850	...
10.00 "	7,850	0.55	0.49	4,550	86
10.30 "	7,610	0.55	0.51	.....	...
11.00 "	7,210	0.45	0.44	.....	...
11.30 "	7,170	0.40	0.39	.....	...
12.00 M.	7,170	0.40	0.39	3,750	104

TABLE B.—Continued.

For the 30 Minutes Ending,	Effluent Quantity, Gallons.	Sulphate of Alumina Used. Total Pounds.	Sulphate of Alumina Used. Grains Per Gallon.	Bacteria Per Cubic Centimeter. Applied Water.	Bacteria Per Cubic Centimeter. Effluent.
12.30 P. M.	7,210	0.45	0.44	.....	...
1.00 "	7,210	0.55	0.53	2,200	82
1.30 "	7,220	0.45	0.44	.....	...
2.00 "	7,240	0.59	0.57	3,100	122
2.30 "	7,170	0.58	0.57	.....	...
3.00 "	7,050	0.56	0.56	2,000	54
3.20 "	Valve Closed for Washing.			.....	...
3.30 "	4,630	0.42	0.63	.....	...
3.40 "	Valve Opened after Washing.			.....	...
4.00 "	5,510	0.46	0.58	2,850	62
4.30 "	8,670	0.60	0.48	.....	...
5.00 "	8,670	0.55	0.44	2,700	36
5.30 "	8,530	0.51	0.42	.....	...
6.00 "	8,530	0.98	0.80	3,850	57
6.30 "	8,410	0.77	0.64	.....	...
7.00 "	8,440	0.63	0.52	2,100	50
7.30 "	8,340	0.66	0.55	.....	...
8.00 "	8,390	0.66	0.55	3,050	43
8.30 "	8,340	0.65	0.55	.....	...
9.00 "	8,240	0.63	0.54	3,150	63
9.30 "	8,230	0.65	0.55	.....	...
10.00 "	8,110	0.61	0.52	2,300	41
10.30 "	8,070	0.58	0.50	.....	...
11.00 "	7,910	0.60	0.53	2,500	50
11.30 "	7,880	0.57	0.51	.....	...
12.00 Mid.	7,700	0.55	0.50	2,750	60
12.30 A. M.	7,550	0.56	0.52	.....	...
1.00 "	7,700	0.54	0.49	3,450	67
1.30 "	7,440	0.64	0.60	.....	...
2.00 "	7,400	0.85	0.80	2,750	74
2.30 "	7,330	0.95	0.91	.....	...
3.00 "	7,600	0.73	0.67	2,450	55
3.30 "	7,320	0.56	0.54	.....	...
4.00 "	7,450	0.62	0.58	2,750	84
4.30 "	6,810	0.55	0.52	.....	...
5.00 "	6,940	0.50	0.50	3,000	54
5.30 "	6,790	0.55	0.57	.....	...
6.00 "	6,670	0.51	0.54	2,300	66
6.30 "	6,780	0.47	0.49	.....	...
7.00 "	6,760	0.57	0.59	3,300	206
7.30 "	6,890	0.55	0.56	.....	...
8.00 "	6,840	0.54	0.55	3,100	136
8.30 "	6,740	0.48	0.50	.....	...
9.00 "	6,380	0.45	0.49	3,550	62

NOTES:—
Changed from Coagulant Tub No. 2 to Coagulant Tub No. 1, at 5.35 P. M., April 14, 1898.
Changed from Coagulant Tub No. 1 to Coagulant Tub No. 2, at 1.19 A. M., April 15, 1898.

TABLE C.

Special Test with the Warren Filter.

Variation in the Application of Coagulant,
From 9.00 A. M. to 10.23 P. M., June 10, 1898.

Time.	Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations,	Grains Per Gallon, Computed from Alkalinity.
9.00 A. M.	.....	2.14	....	....	1.19
9.20 "	.....	2.17	....	....	1.15
9.30 "	6,440	2.12	1.35	1.47	1.21
9.40 "	.....	2.03	....	....	1.33
9.50 "	.....	1.96	....	....	1.41
10.00 "	6,570	1.90	1.44	1.53	1.49
10.10 "	.....	1.93	....	....	1.45
10.20 "	.....	1.67	....	....	1.77
10.30 "	6,640	1.74	1.04	1.10	1.69
10.40 "	.....	2.00	....	....	1.36
10.50 "	.....	2.00	....	....	1.36
11.00 "	7,720	1.94	0.88	0.80	1.44
11.10 "	.....	2.06	....	....	1.29
11.20 "	.....	1.95	....	....	1.43
11.30 "	6,320	2.00	1.54	1.73	1.36
11.40 "	.....	1.96	....	....	1.41
11.50 "	.....	2.10	....	....	1.23
12.00 M.	6,020	2.24	0.79	0.93	1.06
12.10 P. M.	.....	2.22	....	....	1.09
12.20 "	.....	2.31	....	....	0.97
12.30 "	6,210	2.17	0.83	0.94	1.15
12.40 "	.....	2.31	....	....	0.97
12.50 "	.....	2.32	....	....	0.96
1.00 "	5,840	2.23	0.97	1.16	1.08
1.10 "	.....	2.36	....	....	0.91
1.20 "	.....	2.36	....	....	0.91
1.30 "	6,290	2.22	1.11	1.23	1.09
1.40 "	.....	2.29	....	....	1.00
1.50 "	.....	2.19	....	....	1.12
2.00 "	6,940	2.23	1.24	1.24	1.08
2.10 "	.....	2.27	....	....	1.03
2.20 "	.....	2.27	....	....	1.03
2.30 "	5,170	2.43	1.17	1.58	0.83
2.40 "	.....	2.22	....	....	1.09
2.50 "	.....	2.05	....	....	1.30
3.00 "	5,640	2.12	1.24	1.53	1.21
3.10 "	.....	2.18	....	....	1.14
3.20 "	.....	2.15	....	....	1.17
3.30 "	5,440	2.20	0.97	1.25	1.11
3.40 "	.....	2.10	....	....	1.24
3.50 "	.....	2.10	....	....	1.24
4.00 "	5,440	1.96	0.90	1.16	1.41

TABLE C.—Continued.

Time.	Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
4.10 A. M.	.....	2.08	....	....	1.26
4.20 "	.....	2.07	....	....	1.27
4.30 "	5,370	2.38	0.85	1.11	0.89
4.40 "	.....	2.11	....	....	1.22
4.50 "	.....	2.00	....	....	1.36
5.00 "	5,450	2.03	0.95	1.22	1.33
6.00 "	10,250	2.65	1.94	1.34	0.55
7.00 "	12,380	....	2.07	1.17	....
8.00 "	9,050	2.60	1.62	1.25	0.61
9.00 "	10,660	....	3.78	2.48	....
9.30 "	.....	2.50	....	....	0.74
10.00 "	10,550	2.41	1.71	1.13	0.85
10.23 "	.....	2.16	....	....	1.16
Averages,	.....	2.15	....	1.30	1.17

NOTES:—The average alkalinity of the applied water, during the test, was 3.09.
Valve opened after washing, at 8.10 A. M., June 10, 1898.
Valve closed for washing, at 10.24 P. M., June 10, 1898.
Changed from Coagulant Tub No. 2 to Coagulant Tub No. 1, at 11.10 A. M., June 10, 1898.
Changed from Caogulant Tub No. 1 to Coagulant Tub No. 2, at 8.00 P. M., June 10, 1898.

TABLE D.

Special Test with the Warren Filter,

Variation in the Application of Coagulant,
From 9.00 A. M. to 11.13 P. M., June 23, 1898.

Time.	Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
9.00 A. M.	.....	0.64	2.38	2.67	2.26
9.10 "	.....	0.64	....	....	2.26
9.20 "	.....	0.70	....	....	2.19
9.30 "	7,070	1.10	3.12	3.09	1.69
9.40 "	.....	0.60	....	....	2.31
9.50 "	.....	0.85	....	....	2.00
10.00 "	6,890	0.75	2.25	2.28	2.13
10.10 "	.....	0.65	....	....	2.25
10.20 "	.....	0.57	....	....	2.35
10.30 "	6,630	0.98	3.75	3.96	1.84
10.40 "	.....	0.95	....	....	1.88
10.50 "	.....	0.55	....	....	2.38
11.00 "	6,660	0.57	2.04	2.14	2.35
11.10 "	.....	0.82	....	....	2.04
11.20 "	.....	0.52	....	....	2.41
11.30 "	6,270	0.60	1.86	2.08	2.31
11.40 "	.....	0.65	....	....	2.25
11.50 "	.....	0.67	....	....	2.23

TABLE D.—Continued.

Time.		Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
12.00	M.	6,150	0.70	1.65	1.88	2.19
12.10	P. M.	.....	0.60	....	....	2.31
12.20	"	.....	0.65	....	....	2.25
12.30	"	6,030	0.70	1.50	1.74	2.19
12.40	"	.....	0.76	....	....	2.11
12.50	"	.....	0.69	....	....	2.20
1.00	"	5,990	0.72	1.23	1.44	2.16
1.10	"	.....	0.79	....	....	2.08
1.20	"	.....	1.14	....	....	1.64
1.30	"	6,100	0.75	1.68	1.93	2.13
1.40	"	.....	0.80	....	....	2.06
1.50	"	.....	0.73	....	....	2.15
2.00	"	7,110	0.90	1.89	1.86	1.94
2.10	"	.....	1.03	....	....	1.78
2.20	"	.....	0.85	....	....	2.00
2.30	"	.....	0.87	....	....	1.98
2.40	"	.....	0.98	....	....	1.84
2.50	"	.....	0.80	....	....	2.06
3.00	"	11,840	0.82	3.90	2.31	2.04
3.10	"	.....	0.74	....	....	2.14
3.20	"	.....	0.79	....	....	2.08
3.30	"	.....	0.72	....	....	2.16
3.40	"	.....	0.75	....	....	2.13
3.50	"	.....	0.78	....	....	2.09
4.00	"	.....	0.80	....	....	2.06
4.10	"	.....	0.82	....	....	2.04
4.20	"	.....	0.82	....	....	2.04
4.30	"	17,730	0.79	6.30	2.49	2.08
4.40	"	.....	0.62	....	....	2.29
4.50	"	.....	0.65	....	....	2.25
5.00	"	5,820	0.63	2.70	3.25	2.27
5.10	"	.....	0.61	....	....	2.30
5.20	"	.....	0.61	....	....	2.30
5.30	"	.....	0.62	....	....	2.28
6.00	"	10,730	0.62	3.97	2.59	2.28
7.00	"	.....	0.70	....	....	2.19
8.00	"	.....	1.18	....	....	1.59
9.00	"	32,310	1.73	3.60	0.78	0.90
10.00	"	.....	1.84	....	....	0.76
10.25	"	.....	1.90	....	....	0.69
11.00	"	21,430	....	2.02	0.66	....
11.13	"	.....	2.20	....	....	0.31
Averages,		.....	0.83	....	2.19	2.02

NOTES:—The average alkalinity of the applied water, during the above test, was 2.45.
Valve opened after washing, at 8.23 A. M., June 23, 1898.
Valve closed for washing, at 11.19 P. M., June 23, 1898.
Changed from Coagulant Tub No. 1 to Coagulant Tub No. 2, at 10.05 A. M., June 23, 1898.
Changed from Coagulant Tub No. 2 to Coagulant Tub No. 1, at 5.20 P. M., June 23, 1898.

TABLE E.

Special Test with the Warren Filter.

Variation in the Application of Coagulant,
From 9.00 A. M., August 12, to 1.30 A. M., August 13, 1898.

Time.	Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	SULPHATE OF ALUMINA USED. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
9.30 A. M.	9,120	....	1.80	1.38	....
10.00 "	7,470	....	1.50	1.41	....
10.30 "	6,680	....	1.05	1.10	....
11.00 "	6,460	....	1.05	1.14	....
11.30 "	7,040	....	1.20	1.19	....
12.45 P. M.	.....	....	....	....	....
1.00 "	.....	1.10	....	....	1.22
1.10 "	.....	1.30	....	....	0.97
1.11 "	17,410	....	3.00	1.21	....
1.20 "	.....	1.15	....	....	1.16
1.30 "	5,350	1.35	0.90	1.18	0.91
1.40 "	.....	1.15	....	....	1.16
1.50 "	.....	1.00	....	....	1.35
2.00 "	9,260	0.80	5.10	3.86	1.60
2.10 "	.....	0.55	....	....	1.91
2.20 "	.....	0.56	....	....	1.90
2.30 "	8,150	0.56	1.95	1.68	1.90
2.40 "	.....	0.50	....	....	1.98
2.50 "	.....	0.45	....	....	2.04
3.00 "	8,330	0.45	1.20	1.01	2.04
3.10 "	.....	0.32	....	....	2.20
3.20 "	.....	0.32	....	....	2.20
3.30 "	8,150	0.54	3.00	2.58	1.93
3.40 "	.....	0.60	....	....	1.85
3.50 "	.....	0.75	....	....	1.66
4.00 "	7,610	0.75	2.70	2.48	1.66
4.10 "	.....	0.60	....	....	1.85
4.20 "	.....	0.60	....	....	1.85
4.30 "	8,690	0.70	1.80	1.45	1.72
4.40 "	.....	0.60	....	....	1.85
4.50 "	.....	0.55	....	....	1.91
5.00 "	7,180	0.68	1.80	1.76	1.75
5.10 "	.....	0.65	....	....	1.79
5.20 "	.....	0.80	....	....	1.60
5.30 "	7,290	0.95	1.95	1.87	1.41
5.40 "	.....	1.00	....	....	1.35
5.50 "	.....	1.05	....	....	1.29
6.00 "	.....	1.00	....	....	1.35
6.10 "	.....	1.00	....	....	1.35
6.30 "	16,620	1.26	3.00	1.26	1.03

TABLE E,—Continued.

Time.		Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
7.00	"	6,350	1.22	0.90	0.99	1.08
7.30	"	8,010	1.34	1.20	1.05	0.92
8.00	"	7,110	1.38	1.05	1.03	0.87
8.30	"	8,260	1.24	1.65	1.40	1.05
9.00	"	7,220	1.20	2.70	2.62	1.10
9.30	"	7,140	1.00	3.07	3.01	1.35
10.00	"	7,000	0.74	1.65	1.65	1.68
10.30	"	7,540	0.80	1.57	1.46	1.60
11.00	"	7,540	0.88	1.50	1.39	1.50
11.30	"	7,000	1.12	1.27	1.27	1.20
12.00	Mid.	7,180	1.05	1.35	1.32	1.29
12.30	A. M.	7,180	1.30	1.27	1.24	0.97
1.00	"	7,570	1.00	1.20	1.11	1.35
1.30	"	6,890	1.25	0.90	0.91	1.04
1.50	"	.....	1.40	....	....	0.85
Averages,		.....	0.89	....	1.57	1.49

NOTES:—The average alkalinity of applied water, during the above test, was 2.08.
Valve closed for washing, at 12.45 P. M., August 12, 1898.
Valve opened after washing, at 1.11 P. M., August 12, 1898.
Valve closed for washing, at 1.46 A. M., August 13, 1898.
Changed from Coagulant Tub No. 2 to Coagulant Tub No. 1, at 1.30 P. M., August 12, 1898.
Changed from Coagulant Tub No. 1 to Coagulant Tub No. 2, at 8.55 P. M., August 12, 1898.

BACTERIAL EFFICIENCY AFTER WASHING.

It is of considerable interest in mechanical filtration, to determine the bacterial efficiency after washing. Numerous samples were collected, for the purpose of demonstrating this feature, and the results of some of the representative tests are given in the following table. It was also true, at times, that, as the filter became clogged and the time for washing approached, the number of bacteria in the effluent increased, as is exhibited in some of the instances chosen.

TABLE F.

Bacteria in Effluent from Warren Filter at Times of Washing.

Time.	Bacteria Per C. C.	Remarks.
Calendar Date:—March 31, 1898.		
12.28 P. M.	36	
1.49 "	30	
2.20 "	33	
2.36 "	32	
2.50 "	...	V. S.
3.10 "	406	V. O.
3.15 "	520	
3.25 "	166	
3.35 "	120	
3.45 "	103	
3.55 "	83	
Calendar Date:—April 1, 1898.		
2.10 A. M.	51	
2.25 "	50	
2.40 "	43	
2.55 "	54	
3.10 "	45	
3.25 "	85	
3.40 "	39	
3.53 "	...	V. S.
4.09 "	252	V. O.
4.14 "	358	
4.24 "	222	
4.34 "	104	
4.44 "	89	
4.54 "	81	
5.04 "	83	
Calendar Date:—April 1, 1898.		
12.13 P. M.	103	
1.30 "	163	
1.45 "	145	
2.00 "	166	
2.15 "	149	
2.48 "	306	V. S.
3.06 "	166	V. O.
3.11 "	514	
3.16 "	379	
3.26 "	384	
3.36 "	293	
3.51 "	336	
4.34 "	272	
Calendar Date:—April 2, 1898.		
3.10 A. M.	134	
3.25 "	147	
3.40 "	108	
3.55 "	128	
4.10 "	132	
4.25 "	132	
4.35 "	...	V. S.
4.53 "	672	V. O.
4.58 "	494	
5.18 "	236	
5.28 "	198	
5.38 "	147	
5.48 "	148	
5.58 "	143	
6.30 "	100	
Calendar Date:—April 14, 1898.		
1.00 P. M.	32	
2.00 "	122	
3.00 "	54	
3.11 "	65	
3.16 "	77	
3.20 "	...	V. S.
3.40 "	...	V. O.
3.50 "	156	
3.53 "	290	
3.56 "	118	
4.00 "	62	
4.05 "	105	
4.10 "	104	
4.20 "	56	
4.41 "	64	
5.00 "	36	
Calendar Date:—April 20, 1898.		
1.15 A. M.	19	
2.28 "	12	
2.31 "	...	V. S.
2.46 "	735	V. O.
2.49 "	721	
2.52 "	158	
2.56 "	88	
3.01 "	65	
3.06 "	47	
3.16 "	36	
4.17 "	21	
6.46 "	8	

TABLE F,—Continued.

Time.	Bacteria Per C. C.	Remarks.
Calendar Date:—April 21, 1898.		
3.06 A. M.	6	
8.00 "	4	
8.08 "	...	V. S.
8.29 "	...	V. O.
8.31 "	124	
8.34 "	30	
8.40 "	17	
8.51 "	12	
Calendar Date:—April 23, 1898.		
9.06 A. M.	17	
10.00 "	15	
11.00 "	11	
11.30 "	6	
12.00 M.	10	
12.01 P. M.	..	V. S.
12.19 "	..	V. O.
12.25 "	84	
12.28 "	40	
12.38 "	26	
12.58 "	7	
1.18 "	15	
2.00 "	11	
3.02 "	10	
4.00 "	4	
5.00 "	2	
6.15 "	8	
7.00 "	8	
8.00 "	6	
9.01 "	3	
10.00 "	9	
12.00 Mid.	19	
Calendar Date:—April 24, 1898.		
1.00 A. M.	5	
2.00 "	5	
3.02 "	6	
3.45 "	83	
4.13 "	16	
4.16 "	...	V. S.
4.35 "	264	V. O.
4.38 "	52	
4.41 "	35	
4.55 "	12	
5.05 "	18	

Time.	Bacteria Per C. C.	Remarks.
Calendar Date:—June 2, 1898.		
12.01 A. M.	92	
2.07 "	76	
2.14 "	...	V. S.
2.36 "	...	V. O.
2.39 "	625	
2.42 "	475	
2.46 "	550	
2.56 "	400	
3.36 "	16	
6.00 "	16	
Calendar Date:—June 2, 1898.		
6.00 P. M.	42	
8.11 "	64	
8.17 "	...	V. S.
8.38 "	...	V. O.
8.41 "	650	
8.44 "	375	
8.48 "	275	
8.58 "	125	
9.38 "	19	
12.00 Mid.	8	
Calendar Date:—June 6, 1898.		
8.05 P. M.	6	
8.10 "	..	V. S.
8.35 "	..	V. O.
8.36 "	37	
8.39 "	20	
8.43 "	20	
8.53 "	16	
9.33 "	9	

TABLE F.—Continued.

Time.	Bacteria Per C. C.	Remarks.	Time.	Bacteria Per C. C.	Remarks.
Calendar Date:—August 12, 1898.			Calendar Date:—August 13, 1898.		
12.44 P. M.	11		1.50 A. M.	166	V. S.
12.45 "	..	V. S.	2.10 "	...	V. O.
1.11 "	..	V. O.	2.15 "	121	
1.12 "	71		2.18 "	850	
1.15 "	1,025		2.21 "	1,125	
1.18 "	750		2.25 "	525	
1.22 "	1,700		2.35 "	550	
1.32 "	1,475		3.15 "	66	
2.12 "	46				
3.20 "	12				
9.21 "	66				
12.00 Mid.	43				

NOTES:—V. S., means Effluent Valve Closed before Washing.
V. O., " " " Opened after "

The following records, relating to the above tests, are copied from the Monthly Record Sheets:—

Date, 24 Hours Ending 9.00 A. M.	Average Condition of Applied Water. Turbidity.	Bacteria Per C. C.	Sulphate of Alumina. Used,—Grains Per Gallon.
April 1, 1898	0.18	8,500	1.97
" 2, "	0.17	5,375	0.90
" 15, "	0.04	2,980	0.55
" 20, "	0.04	2,750	0.81
" 21, "	0.06	2,162	1.09
" 24. "	0.04	2,410	1.38
June 2, "	0.04	1,700	0.66
" 3, "	0.06	1,420	0.62
" 7, "	0.02	3,460	1.04
August 13, "	0.31	8,850	1.53

SPECIAL EXPERIMENTS, TO SHOW THE EFFECT OF USING DIFFERENT QUANTITIES OF COAGULANT.

During the month of May, 1898, special experiments were undertaken with the the Warren Filter, to determine the effect of passing the water through the bed without the application of coagulant, with very little, and with large amounts of coagulant.

Most of these experiments were carried on when the turbidity was not especially high, that is not above 0.10; in fact, we were obliged to postpone some special ones when the river became too muddy.

The general features of these tests are brought out in the regular monthly tables, but a few of the more important facts are best explained by some special tables. The first one, Table G, shows, in two parts, the effect of discontinuing the use of coagulant and how soon this is made evident by the character of the effluent.

The second, Table H, shows how long it takes for the filter to

recover, after it has been operated without coagulant, when the coagulant has just been applied, and in a large amount. It is a remarkable fact that without the use of coagulant the mechanical filter clogs much more slowly than otherwise. In fact, while operating without coagulant, during the first few days of May, the filter ran 117 hours without washing, and then was only washed because a clear bed was desired to start another experiment.

TABLE G.

Bacteria in Effluent,—No Coagulant Used.

Calendar Date, 1898.	Time.	Bacteria Per C. C.	Remarks.
May 1	8.36 A. M.	.....	Valve Opened after Washing,
" "	9.02 "	.....	Supply of Coagulant Shut Off.
" "	9.30 "	28	
" "	9.45 "	134	Turbid.
" "	10.00 "	358	
" "	10.20 "	644	Very Turbid.
" "	11.00 "	1,120	
" "	1.00 P. M.	1,050	
" "	1.30 "	1,372	
" "	3.20 "	1,322	
" "	5.00 "	1,421	
" "	7.05 "	1,540	
" "	9.03 "	1,162	
" "	11.00 "	1,274	
May 14	9.00 A. M.	20	Supply of Coagulant Shut Off.
" "	11.05 "	15	Valve Opened after Washing, 8.35 P. M., May 13.
" "	12.02 P. M.	850	Slightly Turbid.
" "	12.16 "	900	
" "	12.20 "	1,200	Turbid.
" "	12.45 "	1,300	"
" "	2.10 "	21,000	Very Turbid.
" "	2.27 "	.....	Valve Closed for Washing.
" "	2.53 "	.....	Valve Opened after Washing.
" "	2.55 "	500	
" "	2.58 "	50,575	
" "	3.02 "	225	
" "	3.12 "	60,900	
" "	4.00 "	2,730	
" "	5.26 "	64	
" "	7.00 "	2,400	
" "	9.04 "	3,750	

NOTE:—In examining the first set above it should be noticed that there was a washing a short time prior to the beginning of the test. The last washing, previous to the second test, occurred many hours before, and evidently the filter bed was covered with a coagulated film and prepared to filter for a longer time without any coagulant being added. It may be said of the smaller results, secured shortly after the next washing, at 2.55 P. M., that the samples evidently contained some of the wash water which (as the Jewell effluent was alone used for this purpose, at this time) was better than the water which passed through the bed of the Warren Filter.

TABLE H.

Bacteria in Effluent,—Coagulant Applied at Approximate Rate of Two and Three-Quarters Grains Per Gallon.

Calendar Date, 1898.	Time.	Bacteria Per C. C.	Remarks.
May 6	9.00 A. M.	.....	Began to Supply Coagulant.
" "	9.04 "	1,610	
" "	9.35 "	1,113	Valve Opened after Washing, 6.00 A. M., May 6, 1898.
" "	9.55 "	478	
" "	10.05 "	140	Becoming Clear.
" "	10.20 "	34	Clear.
" "	11.00 "	19	
" "	12.00 M.	2	
" "	3.00 P. M.	2	
" "	5.00 "	3	
" "	7.00 "	7	
" "	9.00 "	6	
" "	11.00 "	5	
" 7	12.03 A. M.	5	
" "	12.12 "	..	Valve Closed for Washing.
" "	12.32 "	..	Valve Opened after Washing.
" "	12.35 "	33	
" "	12.38 "	14	
" "	12.42 "	12	
" "	12.52 "	9	
" "	1.02 "	7	
" "	1.32 "	9	
" "	3.03 "	2	
" "	5.00 "	3	
" "	7.00 "	2	

NOTES:—The above table also shows that washings have less effect when considerable coagulant is used.

The following records, relating to the above tests, are copied from the Monthly Record Sheets:—

Date, 24 Hours Ending 9.00 A. M.	Average Condition of Applied Water. Turbidity.	Bacteria Per C. C.	Sulphate of Alumina Used,—Grains Per Gallon.
May 1, 1898	Windy	4,380	1.15
" 2, "	0.05	4,380	0.00
" 7, "	0.04	3,060	2.73
" 15, "	0.06	7,400	0.00

Tabulation of Results.

The tables presented upon the following pages give the quantitative and bacterial results secured, by days, also the totals and averages for each month. The results of the chemical analyses are given in Appendix No. 2, page 260 et seq.

RECORD OF WARREN MECHANICAL FILTER,

For the Month of January, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	.....
2	...	.....	.....	.....	...	...	.....	...	..	...	.....	.....	.....
3	...	.....	.....	.....	...	...	.....	...	...	...	.....	. ....	.....
4	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	.....
5	...	.....	.....	.....	...	...	.....	...	...	. .	.....	.....	.....
6	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	.....
7	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	.....
8	...	.....	.....	.....	..	.	.....	...	...	...	.....	.....	.....
9	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	.....
10	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	.....
11	...	.....	.....	.....	...	...	.....	...	...		.....	.....	.....
12	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	....
13	...	.....	.....	.....	...	...	.....	...	...	...	.....	.....	.....
14	5.5	89,000	143.000,000	0	0	0	23.8	1.87	0.89	...	30,987	12,950	2,276
15	6.9	106,000	136,000,000	10,000	2	25	38.7	2.55	0.84	...	40,350	11,787	392
16	6.9	83,000	107,000,000	* 8,000	1	16	13.5	1.14	0 48	...	45,325	19,933	1,064
17	0.0	0	0	0	0	0	0.0	0.00	...	...	.....	. ....	. ....
18	8.4	115.000	121,000,000	5,700	1	12	17.2	1.05	0.26	.000	21,275	.....	2,523
19	8.0	137,000	152,000,000	6,300	1	12	30.3	1.55	0.20	.006	22,700	.....	1,381
20	8.6	132,000	136,000,000	7,100	1	27	12.5	0.66	0.12	.000	11,000	.....	382
21	8.4	120,000	127 000,000	5,900	1	14	16.2	0.94	0.16	.000	12,300	.....	323
22	5.1	84,000	146,000,000	10,000	1	18	8.2	0.68	0.16	.000	19,000	.....	494
23	0.0	0	0	0	0	0	0.0	0.00	0.00	...	.....	.....	.....
24	0.0	0	0	0	0	0	0.0	0.00	0.00	...	.....	.....	.....
25	0.0	0	0	0	0	0	0.0	0.00	0.00	...	.....	.....	.....
26	4.6	54,000	104,000,000	5,100	1	9	45.6	5.92	0.19	.000	12,650	.....	1,621
27	5.7	77,000	120,000,000	4,900	1	9	24.7	2.25	0.25	.000	15,000	.....	1,234
28	4.6	53,000	102,000,000	3,400	1	8	16.1	2.13	0.22	...	14,050	.....	414
29	23.3	275,000	105,000,000	11,200	1	20	20.0	0.51	0.11	...	6,825	.....	147
30	22.0	255,000	103,000,000	6,000	1	14	22.6	0 62	0.08	...	2,600	.....	92
31	23.6	282,000	106,000,000	5,200	1	11	27.1	0.67	0.09	...	.....	.....	.....
Tot'ls,	141.6	1,862,000	.....	88,800	14	195	316.5	...	...	...	.....	.....	.....
Av'gs,	10.1	133,000	117,000,000	6,300	1	13.9	22.6	1.19	0.29	.001	19,543	.....	950

NOTES:—Percentage of Bacteria removed, 95.14.

Percentage of Filtrate used for washing, 4.8

Filter not in operation for 72 hours, ending 9.00 A. M., January 25, on account of repairs to the building.

* Wash meter broken; quantity of Wash Water estimated at 500 gallons per minute of actual washing time.

The Warren Effluent Meter was found to register 13 per cent. in excess to March 14, 1897, then 5 per cent. in excess to April 5, and then 4 per cent. in excess after the last date. All effluent quantities are the proper percentage less than the meter records.

There was about 2,400 gallons wasted from the surface of the Warren Filter each time it was washed.

RECORD OF WARREN MECHANICAL FILTER,

For the Month of February, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.5	304,000	115,000,000	7,100	1	15	17.2	0.40	0.08	...	2,350	.....	82
2	23.6	302,000	113,000,000	5,600	1	12	23.5	0.54	0.08	.000	2,250	.....	128
3	23.0	316,000	122,000,000	*15,500	2	31	18.0	0.40	0.09	...	2,775	.....	258
4	23.3	319,000	121,000,000	11,000	2	22	22.6	0.50	0.06	.000	2,700	4,000	378
5	23.1	323,000	124,000,000	11,000	2	22	24.2	0.52	0.05	.000	1,575	2,150	208
6	23.6	292,000	110,000,000	6,000	1	12	18.0	0.43	0.05	.000	1,425	1,175	130
7	23.6	277,000	104,000,000	5,500	1	11	15.9	0.40	...	...	.....	.....	...
8	21.7	221,000	90,000,000	7,000	1	14	16.6	0.53	0.04	...	1,700	1,587	72
9	16.4	211,000	114,000,000	6,000	1	12	10.5	0.35	0.04	...	3,550	3,250	675
10	23.7	282,000	105,000,000	6,000	1	12	29.0	0.72	0.14	.000	.....	.....	...
11	20.0	261,000	115,000,000	10,500	2	21	17.2	0.46	0.26	.000	.....	.....	...
12	18.7	245,000	116,000,000	13,500	3	27	13.7	0.39	0.30	.023	8,025	8,175	343
13	18.0	240,000	118,000,000	11,500	2	23	36.4	1.06	0.48	...	17,500	8,850	161
14	21.7	295,000	120,000,000	23,500	4	47	35.5	0.84	0.47	...	.....	.....	...
15	22.7	275,000	107,000,000	16,500	3	33	50.7	1.29	0.32	.000	25,600	22,600	280
16	22.5	286,000	113,000,000	16,000	3	32	44.3	1.08	0.25	.000	24,150	20,400	350
17	20.5	285,000	123,000,000	*10,000	2	20	70.1	1.72	0.19	.045	23,600	10,800	326
18	0.0	0	0	0	0	0	0.0	0.00	0.13	...	9,250	.....	...
19	20.0	184,000	81,000,000	10,100	1	19	22.6	0.86	0.09	.000	11,025	4,950	265
20	23.7	195,000	73,000,000	6,300	1	10	21.4	0.77	0.08	.000	7,050	3,050	59
21	23.3	201,000	76,000,000	11,000	2	19	23.7	0.82	...	..	.....	.....	...
22	23.7	204,000	76,000,000	6,700	1	10	22.4	0.77	0.16	.023	12,025	3,425	437
23	23.8	208,000	77,000,000	5,000	1	8	8.7	0.29	0.15	.000	10,150	10,125	471
24	20.4	208,000	90,000,000	6,200	1	9	25.5	0.86	0.13	.000	12,350	4,350	197
25	23.1	266,000	102,000,000	12,900	2	18	13.1	0.34	0.11	...	9,400	5,500	85
26	23.6	267,000	100,000,000	6,200	1	10	26.5	0.69	0.08	.000	12,112	6,450	115
27	23.4	274,000	104,000,000	13,100	2	20	33.9	0.87	0.07	.000	7,750	7,450	140
28	22.6	264,000	103,000,000	6,600	1	10	40.0	1.06	0.05	...	8,600	.....	72
Tot'ls,	597.2	7,005,000	.....	266,300	45	499	701.2	...	...	...	. ....	.....	...
Av'gs,	21.3	250,000	104,000,000	9,500	1.6	17.8	25.0	0.70	0.15	.005	9,430	7,127	238

NOTES:—Percentage of Bacteria removed, 97.48.
Percentage of Filtrate used for washing, 3.8.
* Wash meter broken from February 3 to February 17, inclusive. Quantity of Wash Water estimated at 500 gallons per minute of actual washing time.

RECORD OF WARREN MECHANICAL FILTER,

For the Month of March, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration. Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	16.9	189,000	99,000,000	11,500	2	19	16.4	0.61	0.04	.000	6,125	7,450	269
2	22.7	269,000	105,000,000	5,800	1	8	25.4	0.66	0.05	.000	7,650	6,800	236
3	23.6	273,000	102,000,000	3,400	1	7	21.3	0.55	...	.000	7,450	5,475	270
4	23.6	268,000	100,000,000	6,400	1	9	23.8	0.62	0.05	.001	4,925	3,850	63
5	23.3	274,000	104,000,000	11,800	2	18	23.7	0.61	0 06	.000	4,475	3,175	55
6	23.8	271,000	101,000,000	6,200	1	9	18.2	0.47	0.07	.000	5,150	4,865	35
7	23.7	288,000	108,000,000	5,700	1	9	24.6	0.60	...	...	3,400	.....	31
8	23.7	276,000	103,000,000	6,200	1	8	30.1	0.76	0.04	.000	5,100	2,600	35
8	23.7	271,000	101,000,000	6,100	1	8	21.3	0.55	0.05	.000	5,075	3,625	57
10	23.3	268,000	102,000,000	6,100	1	8	22.1	0.58	0.05	.000	5,175	5,000	77
11	23.3	272,000	103,000,000	6,000	1	7	17.9	0.46	0.06	...	5,700	3,650	200
12	23.4	284,000	107,000,000	11,400	2	15	25.0	0.62	0.05	.000	5,475	3,975	450
13	23.3	276,000	105,000,000	9,300	2	14	24.7	0.63	0.05	.000	6,525	6,075	209
14	23.7	279,000	104,000,000	6,100	1	8	28.0	0.70	0.08	...	.....	.....	88
15	19.5	243,000	110,000,000	10,200	2	13	37.7	1.09	0.12	.000	12,025	7,800	498
16	23.3	298,000	113,000,000	9,700	2	15	5.4	1.07	0.12	.000	14,175	10,050	109
17	23.3	301,000	114,000,000	11,300	2	13	49.9	1.16	0.11	.000	12,400	7,700	91
18	23.2	290,000	111,000,000	13,100	2	16	39.0	0.94	0.10	.000	7,350	6,625	206
19	23.7	290,000	108,000,000	7,100	1	9	28.6	0.69	0.09	.000	8,600	10,125	61
20	23.3	304,000	106,000,000	12,200	2	15	62.4	1.44	0.08	.000	9,900	5,850	192
21	11.7	134,000	101,000,000	0	0	0	33.7	1.76	0.49	...	.....	.....	.....
22	14.7	195,000	117,000,000	14,700	2	14	60.7	2.18	0.90	.003	.....	.....	.....
23	20.9	271,000	115,000 000	5,700	1	7	112.0	2.89	1.00	.000	56,000	.....	183
24	22.9	321,000	124,000,000	19,900	3	24	545.8	11.90	2.38	.010	55,483	14 733	699
25	23.2	252,000	96,000,000	12,500	2	15	347.4	9.64	0.90	.010	23,267	7,850	215
26	23.2	300,000	114,000,000	15,600	2	20	206.5	4.82	0.41	...	14,400	4,500	88
27	23.3	303,000	115,000,000	14,500	2	18	61.5	1.42	0.20	.000	7,000	4,775	54
28	23.2	307,000	117,000,000	13,300	2	18	39.7	0.91	0.17	...	4.800	3,200	76
29	23.7	291 000	109,000,000	6 100	1	8	34.2	0.82	0.20	.000	4,750	2,225	116
30	23.1	294,000	113,000,000	15,000	2	16	57.9	1.38	0.29	...	9,967	3,500	44
31	23.2	316,000	121,000,000	11,500	2	15	98.6	2.18	0.50	.000	16,583	14,800	58
Tot'ls,	691.4	8,468,000	.....	294,400	48	383	2183.5	....	...	...	.....	.....	...
Av'gs,	22.3	273,000	108,000,000	9,500	1.5	12.4	70.4	1.81	0.30	.001	11,747	6,164	164

NOTES:—Percentage of Bacteria removed, 98.60.
Percentage of Filtrate used for washing, 3.5.

RECORD OF WARREN MECHANICAL FILTER.

For the Month of April, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration. Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.4	314,000	119,000,000	12,600	2	14	88.4	1.97	0.18	.000	8,500	4,450	69
2	23.4	323,000	122,000,000	11,700	2	14	41.6	0.90	0.17	.000	5,375	5,750	220
3	23.7	321,000	120,000,000	6,200	1	7	34.5	0.75	0.13	.000	5,287	4,175	135
4	23.4	314,000	119,000,000	9,900	2	13	35.2	0.78	0.11	...	3,667	3,600	61
5	13.8	180,000	115,000,000	0	0	0	12.5	0.49	0.08	.000	2,937	3,400	100
6	23.2	330,000	126,000,000	10,400	2	14	27.9	0.59	0.07	.000	2,512	1,900	97
7	23.6	336,000	126,000,000	5,700	1	8	25.0	0.52	0.07	.000	2,562	1,600	134
8	23.7	319,000	119,000,000	4,600	1	7	23.8	0.52	0.08	.000	1,725	1,425	121
9	23.4	327,000	124,000,000	11,300	2	13	24.6	0.53	0.07	.000	2,112	1,800	106
10	23.7	335,000	125,000,000	5,600	1	7	27.2	0.57	0.05	.000	2,925	3,075	91
11	23.7	324,000	121,000,000	6,200	1	7	21.3	0.46	0.04	...	2,917	2,100	33
12	23.7	333,000	125,000,000	5,600	1	7	13.6	0.29	0.04	.000	3,037	3,050	155
13	23.7	332,000	124,000,000	6,100	1	7	23.5	0.50	0.04	.023	3,575	2,925	135
14	23.7	321,000	120,000,000	5,200	1	7	18.7	0.41	0.04	.000	2,537	2,600	59
15	23.7	358,000	134,000,000	6,200	1	9	28.3	0.55	0.04	.000	2,980	2,175	79
16	23.4	362,000	137,000,000	10,500	2	14	28.7	0.56	0.04	.000	2,612	1,717	45
17	23.3	354,000	135,000,000	12,500	2	15	28.6	0.57	0.03	.000	1,525	900	43
18	23.7	369,000	138,000,000	8,100	1	10	36.9	0.70	0.06	...	2,317	1,000	14
19	22.1	294,000	118,000,000	12,000	2	15	30.4	0.72	0.05	...	2,525	1,575	20
20	23.7	321,000	120,000,000	4,600	1	6	37.1	0.81	0.04	.000	2,750	1,225	32
21	23.3	305,000	116,000,000	11,900	2	14	47.7	1.09	0.06	.000	2,162	1,450	6
22	23.7	328,000	123,000,000	5,800	1	7	50.7	1.08	0.05	.000	1,537	775	8
23	22.9	297,000	115,000,000	4,900	1	6	55.0	1.30	0.04	.000	1,425	1,350	39
24	23.4	318,000	120,000,000	10,400	2	13	62.6	1.38	0.04	.000	2,410	725	15
25	23.7	313,000	117,000,000	5,400	1	7	31.4	0.70	0.06	...	7,350	8,750	71
26	23.4	325,000	123,000,000	11,800	2	13	58.0	1.25	0.20	.000	16,000	7,925	137
27	23.4	317,000	120,000,000	10,800	2	13	74.3	1.64	0.23	.000	18,912	9,200	51
28	23.7	303,000	113,000,000	5,600	1	7	62.2	1.44	0.21	.000	17,725	9,275	78
29	19.6	270,000	122,000,000	17,800	3	25	51.4	1.33	0.12	.000	10,587	7,525	140
30	23.6	312,000	117,000,000	6,700	1	8	64.9	1.46	0.09	.000	7,812	3,325	34
Tot'ls,	690.7	9,555,000	.....	246,100	43	307	1166.0	...	...	..	.....	.....	.....
Av'gs,	23.0	318,000	122,000,000	8,200	1.4	10.2	39.0	0.86	0.08	.001	5,010	3 358	78

NOTES.—Percentage of Bacteria removed, 98.44.
Percentage of Filtrate used for washing, 2.6.

RECORD OF WARREN MECHANICAL FILTER,

For the Month of May, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.3	299,000	114,000,000	13,000	2	16	49.2	1.15	...	.000	5,490	3,800	35
2*	24.0	355,000	131,000,000	0	0	0	0.00	0.00	0 05	.002	4,380	3 530	1,160
3*	24.0	345,000	127,000,000	0	0	0	0.00	0.00	0.03	.002	3,120	3,550	900
4*	24.0	333,000	123,000 000	0	0	0	0.00	0.00	0.04	.001	4,090	4,320	770
5*	24.0	318,000	117,000,000	0	0	0	0.00	0.00	0.05	002	4,020	4,350	560
6*	23.5	310,000	117,000,000	14,100	1	17	0.00	0.00	0.04	.002	3,350	2,550	640
7	23.7	319,000	119,000,000	7,700	1	9	124.6	2.73	0.04	015	3,060	2,250	52
8	23.3	322,000	122,000,000	15,900	2	20	136.4	2.97	0.05	.000	4,720	1,350	62
9	23.3	331,000	126,000 000	18,000	2	22	162.1	3.43	0.17	.....	13,500	9,800	55
10	23.6	314,000	118,000,000	76,000	1	10	130.2	2.90	0.28	.000	19,400	7,500	23
11	23.3	324,000	123,000,000	13,000	2	17	111.1	2.40	0.10	.000	8,100	3,120	13
12	23.6	304,000	114,000,000	6,500	1	8	57.6	1.33	0.05	000	4,960	1,350	19
13	23.4	322,000	122,000,000	13,600	2	16	62.6	1.36	0.07	.000	4,310	1,850	12
14	23.6	303,000	114,000,000	6,800	1	9	57.4	1.33	0.04	.000	4,510	1,850	8
15*	23.6	321,000	120,000,000	4,700	1	12	0.00	0.00	0.06	015	7,400	4,600	4,780
16*	23 6	298,000	112,000,000	7,500	1	9	0.00	0.00	0.10	.015	7,050	5,450	3,180
17	23.6	321,000	120,000,000	6,600	1	8	162.4	3.54	0.20	.011	33,600	21,100	890
18	23.6	312,000	117,000,000	7,900	1	11	349.7	7.85	1.20	.018	55,000	24,600	1,540
19	23.1	320,000	123,000,000	20,700	2	29	279.1	6.11	0.40	.018	17,000	12,000	135
20	23.2	313,000	119,000,000	14,300	2	21	25.6	0.57	0.18	.000	12,500	4,020	21
21	23.7	275,000	103,000,000	† 5,600	1	8	52 9	1.35	0.18	.000	12,700	5,600	47
22	23.0	264,000	102,000,000	7,700	1	12	65.6	1.75	0.55	.000	22,800	12,700	96
23	23.7	268,000	100,000,000	7,100	1	10	50.9	1.33	0.40	.000	13,200	4,400	83
24	23.3	270,000	103,000,000	14,800	2	20	49.6	1.29	0.15	.000	13,900	7,200	100
25	23.8	264,000	98,000,000	3,300	1	4	68.0	1.80	0.50	.000	19,500	8,300	58
26	23.6	268,000	101,000,000	7,000	1	10	46.5	1.21	0.31	.000	12,500	7,300	56
27	23.5	265,000	100,000,000	8,400	1	11	29.1	0.77	0.19	.000	6,400	5,050	200
28*	23.6	306,000	115,000,000	7,500	1	11	10.1	0.23	0.11	.100	3,840	2,970	1,160
29*	24.0	279,000	103,000,000	0	0	0	8.7	0.22	0 09	.100	3,410	3,420	1,120
30*	23.1	288,000	110,000,000	8,800	1	12	5.2	0.13	0.10	110	4,070	3,350	1,160
31*	24.0	309,000	114,000,000	0	0	0	4.8	0.11	0.05	.035	1,500	2,130	540
Tot'ls,	730.6	9,440,000	.....	248,100	33	332	2099.4	...	...	...	.....	.....	.....
Av'gs,	23.6	305,000	115,000,000	8,000	1.1	10.7	67.7	1.55	0.19	.015	10,800	6 000	630

NOTES:—Percentage of Bacteria removed, 94.20.

Percentage of Filtrate used for washing, 2.6

Omitting the days starred, when for experimental purposes low quantities of coagulant or none at all were used, the average bacterial results are as follows; river water, 14,400; effluent, 175; bacterial efficiency, 98.78 per cent.

† Wash meter broken; quantity of wash water estimated at 700 gallons per minute of actual washing time.

RECORD OF WARREN MECHANICAL FILTER,

For the Month of June, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.6	297,000	111,000,000	10,200	1	13	15.8	0.37	0.07	035	1,960	1,670	560
2	23 6	277,000	104,000,000	6,500	1	9	26.1	0.66	0.04	.000	1,700	1,300	105
3	23.6	264,000	99,000,000	*8,300	1	11	23.3	0.62	0.06	.000	1,420	4,000	100
4	23.5	277,000	104,000,000	*7,500	1	10	22.0	0.56	0 04	.000	3,020	1,420	115
5	23.6	272,000	102,000,000	*6,700	1	9	21.2	0.55	0.03	.000	2,300	1,670	155
6	23.2	275,000	105,000,000	18,000	2	21	46.1	1.17	0.02	...	3,540	2,050	65
7	23.6	277,000	104,000,000	8,700	1	10	41.1	1.04	0.02	.000	3,460	770	17
8	23.1	261,000	100,000,000	16,500	2	18	40.8	1.09	0.02	.000	12,000	4,950	84
9	23.7	280,000	105,000,000	8,100	1	10	48.0	1.20	0.02	.000	23,400	9,750	84
10	23.2	264,000	101,000,000	15,000	2	16	42.3	1.12	0.02	.000	17,400	9,450	48
11	23.7	276,000	103,000,000	7,600	1	11	48.2	1.22	0.02	.000	28,300	20,400	46
12	23.2	273,000	104,000,000	15,400	2	19	43 9	1.12	0.02	.000	19,500	9,900	88
13	20.6	241,000	104,000,000	13,500	2	16	43.4	1.26	0.02	...	12,400	2,450	59
14	23.5	270,000	102,000,000	5,100	1	7	69.4	1.80	0 03	.000	21,200	8,050	59
15	23.6	286,000	107,000,000	9,200	1	12	68.2	1.67	0.70	.000	27,900	10,700	85
16	23.6	279,000	105,000,000	*8,000	1	10	80.1	2.01	0.80	000	16,500	6,350	43
17	23.2	286,000	109,000,000	*18,400	2	23	53.5	1.31	0.42	.000	7,650	5,700	56
18	23.6	280,000	105,000,000	8,800	1	11	38.5	0.96	0.21	.000	4,250	1,470	48
19	23.6	270,000	101,000,000	7,200	1	10	39.4	1.02	0.15	.000	6,150	6,550	150
20	23.2	277,000	106,000,000	11,600	2	19	98.4	2.49	0.40	.000	28,900	8,300	150
21	23.6	279,000	105,000,000	7,000	1	9	109.3	2.74	0.65	.000	25,100	12,800	98
22	23.7	275,000	103,000,000	7,000	1	9	117.7	3.00	0.70	.000	15,600	8,800	22
23	23.1	252,000	97,000,000	12,900	2	19	103.0	2.86	0.42	.000	5,950	2,200	8
24	23.7	281,000	105,000,000	10,600	1	15	59.7	1.49	0.23	.000	3,500	2,420	24
25	23.6	266,000	99,000,000	8,700	1	13	40.5	1.07	0.12	.000	2,700	2,070	60
26	23.1	269,000	103,000,000	15,800	2	20	52.7	1.37	0.12	.000	4,980	3,060	110
27	23.4	275,000	104,000,000	9,200	1	11	47.6	1.21	0 11	.000	... ..	.....	360
28	23.2	275,000	105,000,000	16,300	2	21	58.7	1.49	0.07	.000	3,770	2,350	43
29	23.3	258,000	98,000,000	12,300	2	17	41.8	1.13	0.07	.000	6,250	4,970	335
30	21.8	255,000	104,000,000	10,200	1	13	47.1	1.29	0.06	.000	11,200	8,100	265
Tot'ls,	699.0	8,167,000	.....	320,300	41	412	1587.8	...	...	...	.....	.....	..
Av'gs,	23.3	272,000	103,000,000	10,700	1.4	13.7	52.9	1.36	0.19	.001	11,100	5,650	115

NOTES:—Percentage of Bacteria removed, 98.96.
Percentage of Filtrate used for washing, 3.9.
* Wash meter broken; quantity of wash water estimated at 750 gallons per minute of actual washing time, July 3, 4, and 5, and 800 gallons July 16 and 17.

RECORD OF WARREN MECHANICAL FILTER,

For the Month of July, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.6	265,000	99,000,000	10,100	1	12	60.3	1.59	0.29	.000	6 000	4,120	41
2	23.3	277,000	105,000,000	15,500	2	19	75.7	1.91	0.22	.075	5,700	2,800	51
3	22.0	256,000	103,000,000	9,300	1	21	89.9	2.46	0.17	.000	5,250	1,870	13
4	20.1	243,000	107,000,000	17,400	2	23	73.8	2.12	0.11	...	4,150	1,600	11
5	1.5	21,000	124,000,000	0	0	0	10.5	3.50	0.09	...	3,150	.....	...
6	23.1	272,000	104,000,000	14,700	2	19	52.9	1.36	0.05	...	6,850	700	2,300
7	23 2	265,000	101,000,000	16,800	2	20	70.4	1.86	0.05	.000	6,350	1,250	68
8	23.6	274,000	103,000,000	8,200	1	10	88.6	2.26	0.08	.000	5,650	1,970	160
9	23.2	275,000	105,000,000	16,300	2	21	54.3	1.38	0.05	.000	10,350	6,250	175
10	23.3	270,000	103,000,000	16,100	2	20	41.4	1.07	0.05	.000	8,100	7,650	900
11	23.6	282,000	106,000,000	7,800	1	9	50.7	1.26	0.04	...	10,250	.....	360
12	23.0	292,000	112,000,000	18.700	2	21	54.1	1.30	0.04	.000	3,850	2,000	125
13	23.3	286,000	109,000,000	15,700	2	18	58.0	1.42	0.05	.000	19,800	9,350	190
14	22.2	323,000	129,000,000	16,900	2	20	65.3	1.42	0.04	.000	40,500	29,900	300
15	23.2	340,000	130,000,000	15,600	2	19	62.9	1.30	0.03	.000	40,200	28,800	590
16	23.2	338,000	129,000,000	16 900	2	20	64.4	1.33	0.08	.000	42,600	34,400	1,250
17	20.5	301,000	130,000,000	8,800	1	11	76.4	1.78	0.80	.000	41,000	28,500	800
18	23.3	335,000	127,000,000	16,500	2	21	76.3	1.59	0.10	000	35,200	18,000	64
19	23.1	339,000	130,000,000	16,300	2	20	53.7	1.11	0.06	.000	14,400	13,500	185
20	23.2	341,000	130,000,000	16,400	2	21	50.3	1.03	0.07	.000	22,600	14,000	185
21	23.2	334,000	127,000,000	19,500	2	23	52.8	1.11	0.19	.000	24,500	18,200	200
22	22.5	331,000	131,600,000	19,900	2	24	55.0	1.16	0.11	.000	20 800	9,700	125
23	23.3	355,000	135,000,000	17,500	2	22	41.7	0.82	0.05	.000	15,200	8,700	58
24	17.5	255,000	129,000,000	0	0	0	32.0	0.88	0.03	.000	8,050	3,670	97
25	0.0	0	0	0	0	0	0.0	0.00	0.06	...	14,600	.....	...
26	0.0	0	0	0	0	0	0.0	0.00	0.06	...	8,750	... ..	...
27	0.0	0	0	0	0	0	0.0	0.00	0.09	...	16,500	.....	...
28	12.6	201,000	141,000,000	25,800	2	30	52.9	1.84	0.06	..	24,500	11,200	95
29	23.2	347,000	132.000,000	17,200	2	21	81.0	1.64	0.05	000	18,500	9,250	65
30	22.8	344,000	134,000,000	27,200	3	34	74.8	1.52	0.05	.000	17,700	11,300	74
31	23.3	362,000	138,000,000	16,600	2	22	72.0	1.39	0.06	000	20,100	6,000	92
Totals	603 9	8,124,000	.....	417,700	48	521	1692.1	...	...	...	.....	.....	...
Av'gs,	19.5	262,000	119,000,000	13,500	1.5	16.8	54.6	1.46	0.11	.003	16,800	10,900	320

NOTES:—Percentage of Bacteria removed, 98.10.
Percentage of Filtrate used for washing, 5.1.
A 350,000 gallon orifice ring was put in Warren Weir, July 13.
Bevel gear on washing apparatus broken July 24.

RECORD OF WARREN MECHANICAL FILTER,

For the Month of August, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.0	350,000	135,000 000	19,300	2	26	110.8	2.22	0.42	...	48,200	9,050	365
2	23.6	368,000	138,000,000	10,200	1	12	133 8	2.55	0.70	.000	27,500	4,550	51
3	23.2	357,000	136,000,000	19,100	2	23	103.8	2.04	0.35	.000	20,200	7,200	48
4	24.0	357,000	137,000,000	27,300	2	35	75.7	1.48	0.15	.000	16,800	8,450	99
5	23.3	352,000	134,000,000	16,600	2	21	80.7	1.60	...	.000	22,300	12,200	230
6	23.2	351,000	134,000,000	19.000	2	23	85.0	1.70	0.80	.000	20,400	13,800	165
7	23.6	360,000	135,000,000	8,500	1	10	65.6	1.28	0.26	.000	9,300	6,500	140
8	23.3	363,000	138 000,000	16,300	2	19	82.2	1.59	0.37	.000	11,400	5,300	39
9	23.2	355,000	135,000,000	19,300	2	22	183.3	3.61	0.28	.000	49,400	32,600	1,530
10	23.1	360,000	138,000,000	19,800	2	23	168.0	3.27	0.92	.035	34,400	13,600	3,100
11	23.2	359,000	137,000,000	20,300	2	24	135.2	2.64	0.55	.000	18,700	5,400	78
12	23.0	356,000	137,000,000	19,600	2	22	126.8	2.49	0.38	.000	9,550	4,100	69
13	23.2	359,000	137,000,000	19,700	2	21	78.6	1.53	0.31	.000	8,850	4,470	165
14	23.2	357,000	136,000,000	21,100	2	24	95.1	1.87	0.60	.000	15,500	12,100	210
15	23.2	364,000	139,000,000	18,900	2	22	96.9	1.86	0.24	...	10,300	5,550	35
16	23.2	363.000	139,000,000	18,900	2	21	68.4	1.32	0.12	.000	4,800	3,120	86
17	23.2	362,000	138,000,000	18,200	2	21	48.7	0.94	0.15	.000	6,450	5,400	160
18	23.6	360,000	135,000,000	8,900	1	10	43.7	0.85	0.08	.000	7,300	4,850	280
19	23.3	357,000	136,000,000	17,200	2	19	68.0	1.33	0.10	.000	10,800	5,700	160
20	23.1	341,000	131,000,000	19,100	2	21	92.4	1.90	0.30	.000	27,300	8,850	340
21	23.1	361,000	138,000,000	21,500	2	25	86.7	1.68	1.75	.400	25,000	19 100	860
22	23.1	360,000	138,000,000	21,000	2	24	106.9	2 08	0.50	.000	22,700	15,300	270
23	22.6	352,000	138,000,000	28,000	3	33	84.7	1.68	0.31	.000	12,600	5,800	21
24	23.2	367,000	140,000,000	18,700	2	21	84.3	1.61	0.26	000	5,600	3 200	26
25	23.3	366,000	139,009,000	14,300	2	18	68.2	1.30	0.18	.000	6,450	2,600	56
26	23.2	364,000	139,000,000	19,500	2	21	66.6	1.28	0.10	.000	1,920	2,370	130
27	23.3	369,000	140,000.000	18,000	2	19	57.9	1.10	0.09	.000	3,500	2,050	36
28	23.6	369,000	139,000,000	10,100	1	11	63.6	1.21	0.18	.000	5,020	4,050	120
29	23.3	368,000	140,000,000	18,200	2	20	72.3	1.38	0.10	...	3,020	3,440	33
30	22.9	360,000	139,000,000	24,700	3	27	76.8	1.49	0.09	.000	1,700	1,370	52
31	23.2	375,000	143,000,000	19,500	2	21	87.4	1.63	0.09	.000	1,520	1,600	65
Tot'ls,	719.5	11,162,000	.....	570,800	60	659	2798.1	...	..	...	.....	.....	.....
Av'gs,	23.2	360,000	137,000,000	18,400	1.9	21.3	90.3	1.76	0.36	.016	15,100	7,550	290

NOTES:—Percentage of Bacteria removed, 98.08.
Percentage of Filtrate used for washing, 5.1.

CHAPTER IV.

JEWELL FILTER EXPERIMENTS.

Description.

The Jewell Filter Plant consisted of a settling basin, an open filter, with a sand area of 113 square feet; a device for adding coagulant to the applied water, and arrangements for washing and agitating the bed. The construction of the filter, as well as all connections, is shown on Plates No. 17 and No. 18, opposite page 182.

Settling Basin.

The settling basin consisted of a space in a circular wooden tank, below the filter proper, which was thirteen feet in diameter inside. This space was seven feet high and held 6,600 gallons, which was equal to the normal flow for thirty-five minutes, when operating the filter at a rate of 105,000,000 gallons per acre daily. The applied water was measured before entering the settling basin by a four-inch meter. As the water entered the basin, it was deflected by a curved iron casting, which directed the current around the wall.

Coagulant.

A solution of sulphate of alumina, prepared as described in Chapter III,* was added to the water through a pipe, which discharged directly into the current of the inflowing water. The solution was lifted by a small steam pump, from one of the tubs in which it was prepared, to a small tank above the filter. From this tank it flowed through an orifice plate, which controlled the rate and which was changed as desired. A constant head was maintained on the orifice by pumping an excess into the tank and allowing the surplus to run back into the original tub.

It should be noted here, that prior to February 15, 1898, the solution of sulphate of alumina was pumped directly into the settling basin from the mixing tubs.

Filter.

The water passed upward from the settling basin to the filter through a central well, 0.58 foot in diameter, which projected 1.48 feet above the surface of the sand. The main body of the sand was a yellow beach sand, with round grains, from Red Wing, Minnesota. Beneath this sand, there was a four-inch layer of crushed quartz. The total depth of sand, on August 31, 1898, was 4.77 feet. The inflow was controlled by a butterfly valve which was operated by a float in a tank, connected with the water in the filter basin.

*See Page 156

The filtered water entered the underdrains through 443 screens beneath the sand. The top of the screen heads projected one inch above the top of the pipes. The screens were composed of punched plates, having nineteen holes to the linear inch in each direction; each hole being 0.025 inch in diamter. The main collecting conduits, were eliptical in shape and had an area of 0.45 square foot, each; and 46 one-inch pipes were screwed into these at right angles to the same. Screens were screwed into holes tapped in the main conduits, into ells at the ends of pipe; and others were fastened into holes in the inch pipes by clamps, which made them fit tightly. All screens were spaced six inches apart on centers. The screens on the main conduits were 0.17 foot higher than the others. The total area of the holes in the screens was 1.36 square feet. The collecting pipes were slightly raised above the wooden floor of the filter, and, in order to give them support, small broken stones were laid underneath and around the pipes. A layer of cement was laid on top of the stones, coming close up under the screen heads.

The five-inch effluent pipe passed through the settling basin and out at one side; beyond which it connected through gates, with the waste pipe to the sewer, with the wash water pipe, and with a six-inch meter, discharging through a regulating device to a clear water reservoir under the floor. All samples of the effluent were collected from a half-inch tap in the effluent pipe. An inch and one-half steam pipe, also connected with the outlet pipe and was used to supply steam for cleansing the filter.

The regulating apparatus was placed over the clear water reservoir. It consisted of an orifice in the bottom of a chamber, which would give the required rate of flow with a given head. When the water filtered through the sand too freely it overflowed into a cup on the side. This cup, by its weight, when full of water, closed a butterfly valve on the effluent pipe. The orifice plate was 9.7 feet below that of the lowest screen in the filter, and 17.0 feet below the level of the water on the filter.

Washing.

Wash water was measured by a four-inch meter and was delivered to the collecting conduits, from which it passed up through the screens and the bed of sand. The rakes were set in motion at the same time. The muddy water flowed over the staves of the filter and was carried off from the space between the walls of the filter and settling basin by an eight-inch pipe leading to the sewer. The upward current lifted the sand from its original position in the bed and during the early washings several inches were carried over the top of the staves.

Occasionally the settling basin was also washed, by allowing the wash water on top of the filter to pass down through the central well,

and out through an eight-inch waste pipe near the bottom. The shaft, connected with the rake arms, ran down through the well and carried on its lower end a curved iron casting. As the rake arms revolved, this casting turned round and directed the current of the water, rushing down through the well, into all parts of the settling basin and flushed out the mud which had settled there.

Agitator.

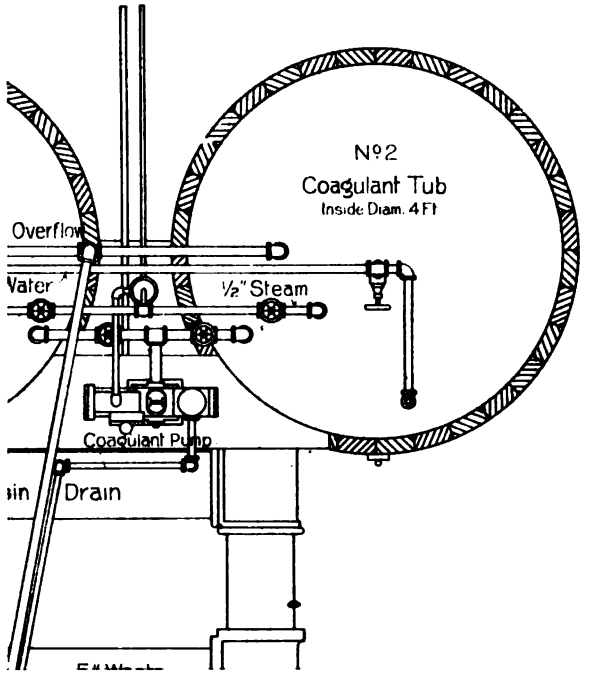
Two beams ran across the filter which supported the gears and shafting and the rake system, which was used to stir the bed. These rakes were made of square bars of iron, four feet long on the long arm, and two feet six inches on the short arm. To the bottom of each of these bars a chain 0.75 foot long was attached. When the rakes hung in a vertical position, the bottom of the chains on the long bars reached to within 2.43 feet, and on the short ones to within 3.59 feet, of the screens. The long rakes were attached to arms which extended nearly the entire way across the filter. The smaller rakes were fastened to short arms, at right angles to the others and near the central well. It was possible to rotate the rakes in either direction, by giving the power to the proper pulley upon the counter shaft. The pulleys were driven by belts from the power shaft at the top of the building and at such a speed that the rakes made about seven turns each minute. Traveling in one direction, the rakes assumed a vertical position and stirred up the bed of sand. When their motion was reversed, they were raised through an arc of about sixty degrees and the lower ends, with the chains, rested on the top of the bed. When rotated slowly in this position, they made furrows about two inches deep in the surface of the sand. This last process was called "Trailing."

Operations.

The filter was put into service on January 21, 1898, and from January 30, it was operated throughout the twenty-four hours. The rate was at first about 85,000,000 gallons per acre daily, but was increased from time to time, until on March 1, 1898, it was about 105,000,000 gallons per acre daily, and continued at about that rate during the rest of the experiments. The same sulphate of alumina was used as with the Warren Filter, and the methods of preparing and computing the amounts used were the same as described in Chapter III.* Beginning with March 24, 1898, the coagulant solution was applied during washing for several minutes before the inlet gate was opened. Interruptions in the operations are noted upon the monthly record sheets.

*See Page 156.

Plate No. 17.


Nº2
Coagulant Tub
Inside Diam. 4 Ft
Overflow
Water
½" Steam
Coagulant Pump
Drain

Sand Used.

During the process of washing the finest particles of sand were carried to the top of the bed and formed there a fine layer which clogged quickly and shortened the periods between washings. In order to correct this effect, sand was removed from the surface, at the request of the filter company, on the following calendar dates:—

February	2, 1898,	—1¼	inches.	March	2, 1898,	— ½	inches.
"	4, "	—1	"	"	4, "	—3	"
"	5, "	— ⅝	"	"	12, "	—1	"
"	14, "	— ½	"	"	14, "	—1½	"
"	26, "	—1½	"	"	30, "	—18	"

When the filter was first put into operation the tops of the staves were twenty-five inches above the surface of the sand. This distance was so great that it prevented the current of wash water from carrying the heavier particles of mud over the staves to the sewer. In order to remedy this difficulty ten inches of sand were added to the filter on February 14, and again on March 2, 1898. On March 30, eighteen inches were removed and twenty-four inches of coarser sand were added. The results of the mechanical analyses of these sands are given in the following table:—

TABLE A.

Mechanical Analyses of Sand Used in Jewell Filter.

Serial No.	Calendar Date of Collection.	Effective Size, M. M.	Uniformity Coefficient.	Depth in Inches.	Remarks.
437	Feb. 2, 1898	0.36	1.4	...	First Consignment.
491	" 2, "	0.39	1.7	....	" "
450	Mar. 24, "	0.46	1.3	....	Last "
492	" 24, "	0.47	1.3	....	" "
453	" 5, "	0.33	1.5	1	
454	" " "	0.41	1.4	6	
455	" " "	0.42	1.4	12	
456	" " "	0.40	1.5	18	Samples collected by tube from the sand in place.
457	" " "	0.42	1.4	24	
458	" " "	0.42	1.4	30	
459	" " "	0.42	1.4	42	
460	" 30, "	0.38	1.3	Surface	
461	" " "	0.41	1.4	Just below	
.....	" " "	0.42	1.4	18	Samples collected by tube from the sand in place.
.....	" " "	0.42	1.4	30	
.....	" " "	0.43	1.4	42	
493	Nov. 15, "	0.46	1.4	....	Average sample, collected after dismantling.

VARIATIONS IN THE RATE OF FILTRATION AND IN THE APPLICATION OF COAGULANT.

As with the Warren Filter, experiments were made to determine the variations in the rate of filtration and in the application of the coagulant. The variations were much less than those with the Warren Filter. The results of the tests are given in the following Tables, B, C, and D:—

TABLE B.

Special Test with the Jewell Filter.

Variations in the Rate of Filtration and in the Application of Coagulant, For the 24 Hours Ending 9.00 A. M., April 15, 1898.

For the 30 Minutes Ending,	Effluent Quantity, Gallons.	Sulphate of Alumina Used. Total Pounds.	Sulphate of Alumina Used. Grains Per Gallon.	Bacteria Per Cubic Centimeter. Applied Water.	Bacteria Per Cubic Centimeter. Effluent.
9.13 A. M.	Valve Closed for Washing.			.....	116
9.27 "	Valve Opened after Washing.			.....	209
9.30 "	2,620	0.10	0.27	3,850	628
10.00 "	5,840	0.35	0.42	4,550	169
10.30 "	6,420	0.28	0.30	.....	...
11.00 "	5,810	0.27	0.33	.....	133
11.30 "	5,840	0.25	0.30	.....	...
12.00 M.	5,210	0.30	0.40	3,750	111
12.30 P. M.	5,810	0.30	0.36	.....	...
1.00 "	5,810	0.25	0.30	2,200	87
1.30 "	5,700	0.30	0.37	.....	...
2.00 "	5,720	0.26	0.32	3,100	65
2.30 "	5,760	0.30	0.36	.....	...
3.00 "	5,630	0.27	0.34	2,000	74
3.30 "	6,010	0.29	0.34	.....	...
4.00 "	5,840	0.27	0.32	2,850	181
4.30 "	5,890	0.27	0.32	.....	...
5.00 "	5,830	0.27	0.32	2,700	105
5.30 "	5,780	0.28	0.34	.....	...
6.00 "	5,750	0.28	0.34	3,850	102
6.30 "	5,660	0.28	0.34	.....	...
7.00 "	5,730	0.26	0.32	2,100	65
7.30 "	5,660	0.28	0.32	.....	...
8.00 "	5,730	0.29	0.35	3,050	73
8.30 "	5,730	0.27	0.33	.....	...
9.00 "	5,580	0.27	0.34	3,150	55
9.30 "	5,770	0.29	0.35	.....	...
10.00 "	5,600	0.28	0.35	2,300	87
10.30 "	5,640	0.27	0.33	.....	...
11.00 "	5,690	0.27	0.33	2,500	62
11.30 "	5,610	0.28	0.35	.....	...
12.00 Mid.	5,500	0.27	0.34	2,750	150
12.30 A. M.	5,780	0.27	0.33	.....	119
1.00 "	5,600	0.27	0.34	.....	158
1.30 "	5,500	0.25	0.32	3,450	160
2.00 "	5,560	0.26	0.33	.....	158
2.30 "	5,650	0.25	0.31	.....	...
2.40 "	Valve Closed for Washing.			.....	...
2.55 "	Valve Opened after Washing.			.....	...
3.00 "	3,170	0.24	0.53	2,450	434
3.30 "	5,740	0.27	0.33	.....	...
4.00 "	5,950	0.29	0.34	2,750	101
4.30 "	5,560	0.21	0.26	.....	...

TABLE B,—Continued.

For the 30 Minutes Ending,	Effluent Quantity, Gallons.	Sulphate of Alumina Used. Total Pounds.	Sulphate of Alumina Used. Grains Per Gallon.	Bacteria Per Cubic Centimeter. Applied Water.	Bacteria Per Cubic Centimeter. Effluent.
5.00 A. M.	5,810	0.22	0.26	3,000	66
5.30 "	5,720	0.27	0.33	.....	...
6.00 "	5,950	0.24	0.36	2,300	143
6.30 "	5,690	0.24	0.30	.....	...
7.00 "	5,790	0.26	0.31	3,300	146
7.30 "	5,790	0.26	0.31	.....	...
8.00 "	5,810	0.25	0.30	3,100	123
8.30 "	5,780	0.26	0.31	.....	...
9.00 "	5,430	0.29	0.37	.....	...

NOTES:—

Changed from Coagulant Tub No. 2 to Coagulant Tub No. 1, at 9.41 A. M., April 14, 1898.
Changed from Coagulant Tub No. 1 to Coagulant Tub No. 2, at 3.31 A. M., April 15, 1898.

TABLE C.

Special Test with the Jewell Filter.

Variation in the Application of Coagulant,

From 6.06 A. M. to 1.30 P. M., June 23, 1898.

Time.	Effluent Quantity, Gallons, Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Sulphate of Alumina Used. Grains Per Gallon, by Weight, Between Observations.	Sulphate of Alumina Used. Grains Per Gallon, Computed from Alkalinity.
6.06 A. M.	.....	1.06	....	....	1.74
6.16 "	.....	2.08	....	....	0.46
6.26 "	.....	1.09	....	....	1.70
6.36 "	6,270	0.83	1.20	1.34	2.03
6.46 "	.....	0.83	....	....	2.03
6.56 "	.....	0.67	....	....	2.23
7.06 "	5,740	0.70	1.35	1.65	2.19
7.36 "	5,910	0.90	2.10	2.48	1.94
8.06 "	6,010	0.93	0.90	1.05	1.90
8.36 "	6,050	0.88	1.65	1.91	1.96
9.00 "	4,580	1.09	0.93	1.42	1.70
9.10 "	.....	1.10	....	....	1.69
9.20 "	.....	1.30	....	....	1.44
9.30 "	5,720	0.95	1.32	1.62	1.88
9.40 "	.....	1.10	....	....	1.69
9.50 "	.....	1.15	....	....	1.63
10.00 "	5,790	1.02	1.71	2.07	1.79
10.10 "	.....	1.07	....	....	1.73
10.20 "	.....	1.10	....	....	1.69
10.30 "	5,720	1.03	1.83	2.24	1.78
10.40 "	.....	1.07	....	....	1.73
10.50 "	.....	0.96	....	....	1.86
11.00 "	5,720	0.89	1.71	2.09	1.95
11.10 "	.....	0.96	....	....	1.86
11.20 "	.....	0.90	....	....	1.94
11.30 "	5,640	0.84	1.83	2.27	2.01

TABLE C,—Continued.

Time.	Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
11.40 A. M.	.....	0.77	....	....	2.10
11.50 "	.....	0.78	....	....	2.09
12.00 M.	5,280	0.70	1.74	2.31	2.19
12.10 P. M.	.....	0.75	....	....	2.13
12.20 "	.....	0.85	....	....	2.00
12.30 "	5,260	0.84	1.74	2.31	2.01
12.40 "	.....	0.65	....	....	2.25
12.50 "	.....	0.69	....	....	2.20
1.00 "	5,560	0.70	1.59	2.01	2.19
1.10 "	.....	0.70	....	....	2.19
1.20 "	.....	0.70	....	....	2.19
1.30 "	6,290	0.70	1.59	1.72	2.19
Averages,	.....	0.93	....	1.90	1.90

NOTES:—The average alkalinity of applied water during the test, was 2.45.
Valve opened after washing at 6.06 A. M., June 23, 1898.
Valve closed for washing at 1.34 P. M., June 23, 1898.
Coagulant Tub No. 2 was in use during the whole time of the test.

TABLE D.

Special Test with the Jewell Filter.

Variation in the Application of Coagulant,

From 9.00 A. M. August 12, to 4.30 A. M. August 13, 1898.

Time.	Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
9.00 A. M.	.....	....	....	....	....
9.30 "	6,380	....	1.05	1.15	....
10.00 "	6,740	....	1.20	1.25	....
10.30 "	4,690	....	1.05	1.57	....
11.00 "	4,910	....	0.90	1.28	....
11.30 "	5,420	....	1.05	1.36	....
3.00 P. M.	38,040	....	6.85	1.26	....
3.25 "	.....	0.85	....	....	1.54
3.30 "	2,680	0.75	0.80	2.09	1.66
3.40 "	.....	0.95	....	....	1.41
3.50 "	.....	0.95	....	....	1.41
4.00 "	5,530	1.00	0.80	1.01	1.35
4.10 "	.....	1.10	....	....	1.22
4.20 "	.....	1.10	....	....	1.22
4.30 "	6,300	1.16	0.70	0.78	1.15

TABLE D,—Continued.

Time.	Effluent Quantity, Gallons Between Observations.	Alkalinity of Effluent, in Terms of Calcium Carbonate, Parts Per 100,000.	Sulphate of Alumina Used. Pounds Between Observations.	Grains Per Gallon, by Weight, Between Observations.	Grains Per Gallon, Computed from Alkalinity.
4.40 P. M.	.....	1.10	....	....	1.22
4.50 "	.....	1.15	....	....	1.16
5.00 "	5,420	1.20	0.80	1.03	1.10
5.10 "	.....	1.10	....	....	1.22
5.20 "	.....	1.20	....	....	1.10
5.30 "	8,580	1.32	0.80	0.65	0.95
5.40 "	.....	1.30	....	....	0.97
5.50 "	.....	1.40	....	....	0.85
6.00 "	.....	1.35	....	....	0.91
6.10 "	.....	1.18	....	....	1.12
6.30 "	9,460	1.42	1.80	1.33	0.82
7.00 "	4,650	1.36	0.60	0.90	0.90
7.30 "	6,120	1.44	1.00	1.14	0.80
8.00 "	5,420	1.42	0.80	1.03	0.82
8.30 "	6,380	1.45	0.90	0.99	0.79
9.00 "	5,390	1.50	0.80	1.04	0.72
9.30 "	5,860	1.50	0.90	1.07	0.72
10.00 "	5,570	1.35	0.90	1.13	0.91
10.30 "	5,860	1.35	0.80	0.96	0.91
11.00 "	5,830	1.68	0.90	1.08	0.50
11.30 "	5,350	1.35	0.80	1.05	0.91
12.00 Mid.	5,570	1.60	0.90	1.13	0.60
12.30 A. M.	5,500	1.56	0.80	1.02	0.65
1.00 "	5,720	1.66	0.90	1.10	0.53
1.30 "	5,130	1.60	0.80	1.09	0.60
2.00 "	5,830	1.50	0.90	1.08	0.72
2.30 "	5,460	1.60	0.70	0.90	0.60
3.00 "	7,150	1.70	1.10	1.08	0.48
3.30 "	4,800	1.70	0.70	1.02	0.48
4.00 "	5,350	1.76	0.70	0.92	0.40
Averages,	.....	1.33	....	1.11	0.93

NOTES:—The average alkalinity of applied water during the test, was 2.08.
Valve closed for washing at 3.07 P. M., August 12, 1898.
Valve opened after washing at 3.25 P. M., August 12, 1898.
Valve closed for washing at 4.35 A. M., August 13, 1898.
Changed from Coagulant Tub No. 2 to Coagulant Tub No. 1, at 12.36 P. M., August 12, 1898.
Changed from Coagulant Tub No. 1 to Coagulant Tub No. 2, at 12.10 A. M., August 13, 1898.

BACTERIAL EFFICIENCY AFTER WASHING.

Washing the sand in a mechanical filter destroys the compactness of the layers. As a result of this disturbance the bacterial efficiency of the filter was generally low after washing. Samples were collected frequently in order to show the effect produced, and the results are given in the following tables. It will be noticed that with large quantities of

coagulant the decrease in efficiency is not as marked as with smaller amounts:—

TABLE E.

Bacteria in Effluent from Jewell Filter, at Times of Washing.

Time.	Bacteria per C. C.	Remarks.
Calendar Date:—April 19, 1898.		
9.16 A. M.	48	
11.48 "	62	
11.51 "	...	V. S.
12.10 P. M.	524	V. O.
12.13 "	630	
12.16 "	560	
12.20 "	217	
12.30 "	122	
2.00 "	54	
6.00 "	79	
Calendar Date:—April 20, 1898.		
3.24 A. M.	59	
3.28 "	...	V. S.
3.46 "	896	V. O.
3.49 "	665	
3.56 "	201	
3.52 "	352	
4.01 "	164	
4.06 "	114	
4.16 "	103	
5.17 "	88	
Calendar Date:—May 3, 1898.		
9.05 A. M.	29	
11.43 "	...	V. S.
12.05 P. M.	...	V. O.
12.08 "	342	
12.11 "	346	
12.15 "	86	
12.25 "	31	
1.30 "	29	
3.15 "	18	
5.00 "	6	
7.00 "	7	
9.00 "	7	

Time.	Bacteria per C. C.	Remarks.
Calendar Date:—May 6, 1898.		
9.06 A. M.	5	
12.00 M.	6	
2.16 P. M.	...	V. S.
2.30 "	...	V. O.
2.36 "	376	
2.39 "	294	
2.43 "	35	
2.53 "	12	
3.30 "	5	
5.00 "	8	
7.00 "	4	
9.04 "	3	
11.00 "	10	
Calendar Date:—June 4, 1898.		
2.23 A. M.	1	
2.25 "	..	V. S.
2.42 "	..	V. O.
2.45 "	10	
2.48 "	9	
2.52 "	6	
3.02 "	4	
3.42 "	1	
6.02 "	2	
Calendar Date:—June 5, 1898.		
5.05 A. M.	1	
5.08 "	.	V. S.
5.21 "	.	V. O.
5.24 "	7	
5.27 "	9	
5.31 "	6	
5.42 "	6	
6.21 "	5	

NOTES:—V. S., means Effluent Valve Closed before Washing.
V. O., " " " Opened after "

TABLE E,—Continued.

The following records, relating to the above tests, are copied from the Monthly Record Sheets:—

Date, 24 Hours Ending 9.00 A. M.	Average Condition of Applied Water. Turbidity.	Bacteria Per C. C.	Sulphate of Alumina Used,—Grains Per Gallon.
April 20, 1898	0.04	2,750	0.47
May 4, "	0.04	4,090	0.92
May 7, "	0.04	3,060	0.96
June 4, "	0.04	3,020	3.95
June 5, "	0.03	2,300	4.04

MECHANICAL EFFECT OF TRAILING.

When the filter had been in operation for a few hours after washing the top layer of the sand became clogged. As a result of this the loss of head increased and when it reached about eleven feet the surface was trailed. By this treatment furrows were made on the top of the sand, and, after trailing, the loss of head decreased materially. The filter was operated without trailing from May 22 to June 7, 1898. When the bed of sand was new, and, to a lesser extent, shortly after it had been cleansed with caustic soda, trailing increased the length of the runs between washings. But when the bed had become clogged after a service of many weeks, the trailing failed to produce the former increase in length of runs. These facts are illustrated in the following table:—

TABLE F.

Loss of Head with Jewell Filter before and after Trailing.

Number of Trailing.	Calendar Date and Time, 1898. Valve Opened After Last Washing.	Began to Trail.	Loss of Head in Feet. Before Trailing.	After Trailing.	Recovery.
1	Mar. 31, 3.56 A. M.	Mar. 31, 10.23 A. M.	11.44	6.80	4.64
2	" " " "	" " 3.05 P. M.	11.19	10.53	0.66
1	" " 5.26 P. M.	" " 10.45 "	11.30	6.20	5.10
2	" " " "	Apr. 1, 4.40 A. M.	11.30	8.25	3.05
1	Apr. 1, 7.50 A. M.	" " 12.16 P. M.	11.50	6.54	4.96
2	" " " "	" " 5.25 "	10.93	8.32	2.61
3	" " " "	" " 8.15 "	10.90	9.95	0.95
1	" 4, 5.16 "	" 4, 12.50 "	10.70	7.40	3.30
2	" " " "	" " 7.50 "	10.87	9.23	1.64
3	" " " "	" " 10.02 "	11.09	10.77	0.32
1	" 6, 5.50 "	" 6, 6.23 "	10.70	7.30	3.40
2	" " " "	" " 10.35 "	10.70	9.90	0.80
3	" " " "	" " 11.40 "	10.65	10.50	0.15
1	June 13, 5.32 P. M.	June 14, 6.20 A. M.	11.10	10.00	1.10
2	" " " "	" " 7.12 "	11.15	11.10	0.05
1	" 21, 5.32 A. M.	" 21, 4.35 P. M.	11.25	9.75	1.50
2	" " " "	" " 5.50 "	11.60	11.40	0.20
1	Aug. 5, 6.45 P. M.	Aug. 6, 3.55 A. M.	11.30	9.60	1.70
1	" 6, 5.12 A. M.	" " 1.45 P. M.	11.05	8.20	2.85
1	" 7, 10.04 "	" 7, 5.50 "	11.20	10.15	1.05
1	" 8, 3.06 "	" 8, 12.15 "	11.10	9.00	*2.10
1	" 9, 10.03 P. M.	" 10, 9.26 A. M.	10.95	7.00	3.95
2	" " " "	" " 2.59 P. M.	10.95	10.00	0.95
1	" 10, 6.40 "	" 11, 8.05 A. M.	11.15	8.75	2.40
1	" 11, 11.35 A. M.	" 12, 1.05 "	11.10	9.45	1.65

*NOTES:—Soda Ash was applied to the filter bed, at 2.35 P. M., August 8, 1898, and effluent valve was opened, at 5.06 A. M., August 9, 1898.

The following records, relating to the above tests, are copied from the Daily Record Sheets :—

TABLE F,—Continued.

Date, 24 Hours Ending 9.00 A. M., 1898.	Turbidity of Applied Water.	Sulphate of Alumina Used,—Grains Per Gallon.	Quantity of Wash Water, Gallons.	Duration of Washing in Minutes.
March 31	0.50	0.99	5,170	8
April 1	0.18	1.24	4,480	6
" 1	0.18	1.24	4,670	6
" 4	0.11	0.37	4,100	5
" 6	0.07	0.37	4,550	5
June 14	0.03	1.13	5,400	8
" 21	0.65	1.72	7,100	10
August 6	0.80	1.30	6,760	9
" 6	0.80	1.30	6,450	9
" 8	0.37	0.99	7,970	9
" 10	0.92	1.83	11,050	13
" 11	0.55	1.46	9,710	12
" 12	0.38	1.50	8,620	11

BACTERIAL EFFICIENCY AFTER TRAILING.

The effect produced by trailing on bacterial efficiency is illustrated by the records in the following table:—

TABLE G.

Bacteria in Effluent from Jewell Filter at Times of Trailing.

Calendar Date, 1898.	Time.	Bacteria Per C. C.	Remarks.
May 1,	8.10 A. M.	32	Five Minutes before Trailing.
" 1,	8.20 "	27	Trailing.
" 1,	8.25 "	133	Five Minutes after Trailing.
" 1,	8.30 "	19	Ten Minutes after Trailing.
June 13,	8.43 "	21	Just before Trailing.
" 13,	8.46 "	20	During Trailing.
" 13,	8.55 "	244	Five Minutes after Trailing.
" 13,	9.06 "	27	
" 13,	12.05 P. M.	17	
June 20,	9.35 A. M.	218	
" 20,	2.28 P. M.	198	Before Trailing.
" 20,	2.33 "	190	During Trailing.
" 20,	2.37 "	1,866	
" 20,	2.40 "	693	
" 20,	2.44 "	260	
" 20,	2.54 "	172	
" 20,	3.19 "	253	
" 20,	10.12 "	151	

NOTE :—The following records, relating to the above tests, are copied from the Monthly Record Sheets :—

Date, 24 Hours Ending 9.00 A. M.	Average Condition of Applied Water. Turbidity.	Bacteria Per C. C.	Sulphate of Alumina Used,—Grains Per Gallon.
May 1	Windy	5,490	0.96
June 13	0.02	12,400	1.33
" 14	0.03	21,200	1.13
" 21	0.65	25,100	1.72

EFFECT OF CLEANSING WITH SODA ASH.

On February 15, and on August 8, 1898, the filter was cleansed with a solution of soda ash and then washed thoroughly. One hundred pounds of soda ash were dissolved and thrown upon the surface of the water. A jet of steam was then applied through the underdrains, until the water in the filter boiled. After boiling for ten minutes, the steam was shut off and the filter allowed to stand until the water became cold. The bed was then washed in the usual manner, but longer and with more water. Just before cleansing the filter in February, ten inches of sand were added to the bed. The bacterial results obtained at this time may have been influenced by the new sand. For this reason only those results are given which were obtained on August 8, 1898. One effect of such a cleansing was to renew the life of the bed in such a way, that the time between washings was lengthened, and trailings became more effective, and a greater number between washings were used.

TABLE H.

Bacterial Efficiency with Jewell Filter, at Time of Cleansing with Soda Ash.

Calendar Date, 1898.	Time.	Bacteria Per C. C.	Remarks.
August 8,	9.26 A. M.	89	
" 8,	1.55 P. M.	78	
" 8,	2.12 "	..	Valve Closed.
" 8,	2.35 "	..	Bed Cleansed with 100 Pounds of Soda Ash and Boiled.
" 9,	5.06 A. M.	..	Valve Opened.
" 9,	5.17 "	90	
" 9,	5.22 "	98	
" 9,	5.32 "	728	
" 9,	5.42 "	1,323	
" 9,	5.57 "	1,337	
" 9,	6.12 "	1,043	
" 9,	7.10 "	868	
" 9,	9.48 "	412	

NOTE :—The following records, relating to the above tests, are copied from the Monthly Record Sheets :—

Date, 24 Hours Ending 9.00 A. M.	Average Condition of Applied Water.		Sulphate of Alumina Used,—Grains Per Gallon.
	Turbidity.	Bacteria Per C.C.	
August 9	0.28	49,400	2.52

SPECIAL EXPERIMENTS,

TO SHOW THE EFFECT OF USING DIFFERENT QUANTITIES OF COAGULANT.

Special tests were made during the month of June, 1898, to show the effect which various quantities of coagulant would produce on the bacterial efficiency of the Jewell Filter. The quantity of sulphate of alumina was varied from zero to four grains per gallon.

The results obtained are given in the following table, and are arranged to show the rapidity with which the change in the quantity of coagulant affected the bacterial efficiency:—

TABLE I.

Bacteria in Effluent,—No Coagulant Used.

Calendar Date, 1898.	Time.	Bacteria Per C. C.	Remarks.
June 1,	9.01 A. M.	..	Supply of Coagulant Shut Off, Clear.
" 1,	9.05 "	15	
" 1,	9.45 "	25	
" 1,	10.06 "	..	Valve Closed for Washing.
" 1,	10.24 "	..	Valve Opened after Washing.
" 1,	10.27 "	500	
" 1,	10.30 "	600	Cloudy.
" 1,	10.34 "	550	
" 1,	10.44 "	750	
" 1,	11.24 "	600	

NOTE:—Valve opened after washing, at 10.30 P. M., May 31, 1898.

June 7,	8.40 A. M.	..	Supply of Coagulant Shut Off.
" 7,	8.50 "	14	
" 7,	9.10 "	11	Clear.
" 7,	10.05 "	572	
" 7,	10.40 "	1,050	
" 7,	12.00 M.	2,904	

NOTE:—Valve opened after washing, at 6.10 A. M., June 7, 1898.

TABLE J.

Bacteria in Effluent,

Coagulant Applied at Approximate Rate of Four Grains per Gallon.

Calendar Date, 1898.	Time.	Bacteria Per C. C.	Remarks.
June 3,	8.58 A. M.	375	
" 3,	9.01 "	1,200	Began to Supply Coagulant.
" 3,	9.15 "	450	
" 3,	9.30 "	128	
" 3,	9.48 "	94	Clear.
" 3,	10.03 "	58	
" 3,	12.00 M.	3	

NOTE:—Valve opened after washing, at 12.04 A. M., June 3, 1898.

TABLE J.—Continued.

Coagulant Applied at Approximate Rate of One and One-half Grains per Gallon.

Calendar Date, 1898.	Time.	Bacteria Per C. C.	Remarks.
June 11,	9.01 A. M.	.....	Began to Supply Coagulant.
" 11,	9.08 "	7,900	
" 11,	9.20 "	7,982	
" 11,	9.40 "	1,113	
" 11,	10.00 "	468	
" 11,	10.20 "	328	
" 11,	10.40 "	246	
" 11,	11.23 "	232	
" 11,	12.00 M.	304	Clear.
" 11,	2.40 P. M.	...	
" 11,	3.08 "	182	

NOTES:—Valve opened after washing, at 4.55 A. M., June 11, 1898.

The following records, relating to the above tests, are copied from the Monthly Record Sheets:—

Date, 24 Hours Ending 9 00 A. M.	Average Condition of Applied Water. Turbidity.	Bacteria Per C. C.	Sulphate of Alumina Used,—Grains Per Gallon.
June 2, 1898	0.04	1,700	0.00
" 3, "	0.06	1,420	0.00
" 4, "	0.04	3,020	3.95
" 7, "	0.02	3,460	1.92
" 8, "	0.02	12,000	0.00
" 11, "	0.02	28,300	0.00
" 12, "	0.02	19,500	1.46

Tabulation of Results.

The tables presented upon the following pages give the results secured, by days, also the totals and averages for each month. The results of the chemical analyses are given in Appendix No. 2, page 262 et seq.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of January, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	...	.....	.....	.....	...	...	...	...	...	...	... ..	.....	...
2	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
3	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	..
4	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
5	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
6	...	.....	.....	.....	...	...	...	...	...	...	... ..	.....	...
7	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
8	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
9	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
10	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
11	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
12	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
13	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
14	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
15	...	.....	....	.....	...	..	...	...	...	...	.....	.....	...
16	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
17	...	.....	.....	.....	...	...	...	...	...	...	.....	.....	...
18	...	.....	.....	.....	...	. .	...	...	...	...	.....	.....	...
19	...	.....	.....	.....	...	...	...	...	...	...	.....	. ....	...
20	...	.....	.....	.....	...	..	...	...	...	...	.....	.....	.
21	...	.....	.....	.....	..	...	...	...	...	...	.....	.....	...
22	3.8	36,900	90,000,000	5,100	1	13	5.8	1.10	0.16	...	19,000	.....	5,114
23	1.8	16,500	85,000,000	0	0	0	0.7	0.30	0.19	.030	20,450	.....	5,675
24	0.0	0	0	0	0	0	0.0	0.00	...	...	.....	.....	...
25	0.0	0	0	0	0	0	0.0	0.00	...	...	.....	.....	...
26	4.0	35,600	82,000,000	2,300	1	17	5.9	1.16	0.19	.000	12,650	.....	390
27	4.3	31,600	68.000,000	0	0	0	4.9	1.08	0.25	.000	15,000	.....	393
28	4.5	43,800	90,000,000*	7,700	1	17	4.9	0.78	0.22	..	14,050	.....	554
29	5.8	52,400	84 000,000	0	0	0	5.8	0.77	0.11	...	6,825	.....	759
30	19.1	177,000	86,000,000*	11,200	2	25	18.5	0.73	0.08	...	2,600	.....	956
31	21.4	205,000	89,000,000*	26.600	3	59	15.2	0.52	0.09	...	.....	.....	...
Tot'ls,	64.7	598,800	.....	52,900	8	131	61.7	...	...	...	.....	.....	...
Av'gs,	8.1	74,800	85,000,000	6,600	1	16.4	7.7	0.72	0.16	...	12,939	.....	1,977

NOTES:—Percentage of Bacteria removed, 84.72.
Percentage of Filtrate used for washing, 8.8.
Filter not in operation for the 48 hours ending 9.00 A. M., January 25, on account of repairs to the building.
*Wash meter broken; quantity of wash water estimated at 450 gallons per minute of actual washing time.
The Jewell Effluent Meter was found to register 2 per cent. in excess and all effluent quantities are the proper percentage less than the meter records.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of February, 1898.

Date for 24 Hours Ending 9 00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	20.1	213,000	98,000,000	*11,200	2	25	5 6	0.18	0.08	.000	2,350	.....	150
2	22.6	195,000	80,000,000	*18,900	4	42	8.0	0.29	0 08	.000	2,250	.....	293
3	20.4	204,000	92,000,000	*14,400	3	32	10.7	0.37	0.09	...	2,775	2,700	463
4	22.3	228,000	95,000,000	* 9,900	2	22	12 0	0.37	0.06	.000	2,700	2,800	481
5	22.0	240,000	101,000,000	*15,700	3	35	14.3	0.42	0.05	.000	1,575	1,725	202
6	21.4	226,000	98,000,000	*19,300	3	43	17.2	0.53	0.05	.000	1,425	1,750	192
7	23.2	242,000	96,000,000	*11,700	2	26	17.3	0.50	...	...	.....	.....	...
8	19.4	201,000	96,000,000	*14,400	2	32	11.9	0.41	0.04	...	1,700	1,525	175
9	18.5	193,000	96,000,000	* 9,900	2	22	12.4	0.45	0.04	...	3,550	5,375	1,075
10	22.1	241,000	101,000,000	*14,800	3	33	17.8	0.52	0.14	.000	.....	.....	...
11	19.5	205,000	97,000,000	12,100	2	28	14.9	0.51	0.26	.000	.....	.....	...
12	22.6	198,000	81,000,000	19,400	4	46	14.2	0.50	0.30	.000	8,025	6,225	383
13	17.8	169,000	88,000,000	21,300	3	45	20.0	0.83	0.48	...	17,500	10,700	625
14	21.2	204,000	89,000,000	25,700	4	36	24.0	0.82	0.47	...	.....	.....	...
15†	...	... ..	.....	2,000	...	...	...	...	0.32	...	25,600	.....	...
16	18.6	201,000	100,000,000	17,800	3	40	26.5	0.92	0.25	.000	24,150	23,200	3,831
17	20 0	216,000	100,000,000	8,300	2	13	21.2	0.69	0.19	.045	23,600	16,300	3,413
18	22.9	225,000	91,000,000	11,600	2	18	17.5	0.54	0.13	.015	9,250	8,350	512
19	23.5	267,000	105,000,000	8,500	2	18	23.9	0.63	0.09	.000	11,025	6,875	271
20	23.0	253,000	102,000,000	18,300	3	33	24.6	0.68	0.08	.000	7,050	4,325	613
21	23.5	262,000	105,000,000	9,600	2	18	20.1	0.54	...	...	.....	.....	...
22	20.7	233,000	104,000,000	8,900	2	19	24.0	0.72	0.16	.023	12,025	6,675	134
23	22.4	253,000	104,000,000	8,400	2	18	22.2	0 61	0.15	.000	10,150	8,375	287
24	23.5	260,000	102,000,000	9,300	2	17	25.3	0.68	0.13	.000	12,350	7,525	169
25	23.2	260,000	104,000,000	14,200	3	26	21.9	0.59	0.11	.000	9,400	5,500	305
26	23.7	268,000	104,000,000	5,200	1	8	21.9	0.58	0.08	.000	12,112	9,175	117
27	23.2	263,000	105,000,000	15,600	3	25	21.8	0.58	0.07	.000	7,750	7,525	192
28	19.4	221,000	105,000,000	15,200	3	24	17.6	0.56	0.05	...	8,600	.....	153
Tot'ls,	580.7	6,139,000	.....	371,600	69	744	488.8	...	...	...	.... .	.....	...
Av'gs,	20.7	219,000	98,000,000	13,300	2.5	26.6	17.5	0.56	0.15	.004	9,430	7,191	638

NOTES:—Percentage of Bacteria removed, 93.23
Percentage of Filtrate used for washing, 6.1.
*Wash meter broken; quantity of wash water estimated at 450 gallons per minute of actual washing time.
† Filter cleansed,—100 pounds of Soda Ash used with steam.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of March, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	21.6	252,000	108,000,000	6,500	2	14	23.0	0.64	0.04	.000	6,125	8,225	145
2	22.4	257,000	106,000,000	9,700	2	15	22.1	0.60	0.05	.000	7,650	6,425	145
3	17.4	200,000	106,000,000	11,500	3	24	18.0	0.63	...	...	7,450	5,500	141
4	19.3	221,000	106,000,000	10,600	3	21	26.6	0.84	0.05	.001	4,925	3,675	204
5	23.3	270,000	107,000,000	8,600	2	16	31.9	0.83	0.06	.000	4,475	4,700	100
6	22.8	263,000	107,000,000	8,300	2	19	31.8	0.85	0.07	.000	5,150	2,425	90
7	23.5	270,000	106,000,000	8,400	2	14	29.9	0.77	...	...	3,400	.....	108
8	23.4	271,000	107,000,000	8,600	2	16	24.4	0.63	0.04	.000	5,100	3,875	89
9	23.0	265,000	107,000,000	8,200	2	15	27.5	0.73	0.05	.000	5,075	3,900	94
10	23.5	272,000	107,000,000	9,600	2	14	29.9	0.77	0.05	.000	5,175	3,450	81
11	23.5	269,000	106,000,000	8,300	2	13	30.8	0.80	0.06	...	5,700	2,700	94
12	23.3	265,000	105,000,000	16,800	3	24	29.3	0.77	0.05	.000	5,475	4,175	109
13	23.6	273,000	107,000,000	8,300	2	12	32.0	0.82	0.05	.000	6,525	4,800	120
14	23.0	265,000	107,000,000	14,400	3	20	24.1	0.64	0.08	...	.....	.....	202
15	16.3	190,000	108,000,000	4,500	2	10	17.6	0.65	0.12	.006	12,025	8,950	462
16	23.3	264,000	105,000,000	13,600	3	19	32.7	0.87	0.12	.006	14,175	7,925	258
17	23.4	268,000	106,000,000	8,500	2	12	31.6	0.82	0.11	.006	12,400	4,720	339
18	23.2	264,000	105,000,000	13,200	3	19	30.8	0.82	0.10	.000	7,350	7,650	252
19	23.5	267,000	105,000,000	7,900	2	12	32.2	0.84	0.09	.000	8,600	9,025	166
20	23.4	268,000	106,000,000	12,300	3	17	32.8	0.86	0.08	.000	9,900	.....	269
21	23.2	271,000	108,000,000	15,300	3	22	45.9	1.18	0.49	...	.....	.....	...
22	21.0	232,000	102,000,000	10,600	2	15	53.6	1.62	0.90	.003	.....	.....	...
23	20.1	225,000	104,000,000	18,500	4	27	71.1	2.23	1.00	.000	56,000	.....	1,036
24	23.2	260,000	104,000,000	16,900	3	21	125.4	3.37	2.38	.000	55,483	16,667	642
25	23.4	263,000	104,000,000	8,700	2	13	129.7	3.46	0.90	.003	23,267	9,383	245
26	23.2	261,000	104,000,000	14,700	3	19	58.1	1.56	0.41	...	14,400	6,183	118
27	23.3	265,000	105,000,000	12,900	3	19	21.5	0.57	0.20	.000	7,000	5,275	216
28	23.3	266,000	106,000,000	11,000	2	12	36.3	0.95	0.17	...	4,800	2,300	126
29	23.4	264,000	104,000,000	9,300	2	13	35.6	0.94	0.20	.000	4,750	2,225	98
30	23.1	263,000	105,000,000	9,700	2	11	43.7	1.16	0.29	.000	9,967	2,200	27
31	14.8	171,000	107,000,000	13,800	2	21	24.1	0.99	0.50	.000	16,583	8,200	78
Tot'ls,	688.7	7,875,000	.....	339,200	75	519	1204.0	...	...	...	.....	.....	.....
Av'gs,	22.2	254,000	106,000,000	10,900	2.4	16.7	3.88	1.07	0.30	.001	11,747	5,782	208

NOTES:—Percentage of Bacteria removed, 98.23.
Percentage of Filtrate used for washing, 4.3.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of April, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	22.1	252,000	105,000,000	9,200	2	12	44.6	1.24	0.18	.003	8,500	4,625	76
2	23.7	268,000	105,000,000	4,000	1	6	25.4	0.66	0.17	.000	5,375	5,225	283
3	21.2	241,000	105,000,000	9,000	2	14	15.3	0.44	0.13	.000	5,287	3,575	245
4	23.8	271,000	105,000,000	4,100	1	5	14.3	0.37	0.11	...	3,667	3,300	162
5	23.7	264,000	103,000,000	5,200	1	7	15.4	0.41	0.08	.000	2,937	2,185	152
6	23.4	275,000	109,000,000	8,900	2	12	14.6	0.37	0.07	.000	2,512	2,250	113
7	23.7	270,000	105,000,000	3,600	1	6	11.9	0.31	0.07	.000	2,562	1,725	122
8	23.4	268,000	106,000,000	7,900	2	14	13.9	0.36	0.08	.000	1,725	1,825	91
9	23.0	269 000	108,000,000	5,300	1	6	13.1	0.34	0.07	.000	2,112	1,700	91
10	19.8	244,000	114,000,000	9,100	2	13	12.2	0.35	0.05	.000	2,925	2,650	160
11	23.8	264,000	102,000,000	3,900	1	6	12.9	0.34	0.04	...	2,917	1,950	67
12	23 4	269,000	106,000,000	10,000	2	12	12.9	0.34	0.04	.000	3,037	2,125	124
13	23 6	269,000	105,000,000	9,400	2	12	11.1	0.29	0.04	000	3,575	3,250	136
14	23.7	272,000	106,000,000	6,000	1	7	14.0	0.36	0.04	000	2,537	3,600	115
15	23.5	270,000	106,000,000	8,700	2	13	13.0	0.34	0.04	000	2,980	2,733	134
16	23.7	272,000	106,000,000	3,700	1	5	12.8	0.33	0.04	.000	2,612	2,817	145
17	23.7	271,000	106,000,000	3,800	1	5	13.8	0.36	0.03	.000	1,525	2,000	116
18	23.0	262,000	105,000,000	4,300	1	6	17.8	0.48	0.06	...	2,317	2,000	46
19	15.4	172,000	103,000,000	5,500	1	7	10.4	0.42	0.05	...	2,525	2,025	81
20	23.4	263,000	104,000,000	8,800	2	12	17.6	0.47	0.04	.000	2,750	2,450	96
21	23.7	271,000	106,000,000	5,000	1	6	19.4	0.50	0.06	.000	2,162	1,625	34
22	23.2	266,000	106,000,000	8,800	2	12	17.9	0.47	0.05	.000	1,537	950	25
23	21.5	248,000	107,000,000	8,300	2	11	15.5	0.44	0.04	.000	1 425	1,650	45
24	23.7	273,000	106,000,000	4,600	1	6	17.6	0.45	0.04	.000	2,410	1,150	68
25	23 5	267,000	105,000,000	9,200	2	13	25 3	0.66	0.06	...	7,350	4,000	177
26	23.3	264,000	105,000,000	13,400	3	17	31.5	0.83	0.20	.000	16,000	10,300	570
27	23.6	267,000	105 000,000	8,300	2	12	44.6	1.17	0.23	.000	18,912	9,850	310
28	23.2	263,000	105,000,000	14,200	3	18	45.0	1.20	0.21	.001	17,725	9,900	548
29	23.5	266,000	105,000,000	10,400	2	12	38.4	1.01	0.12	.000	10,587	10,150	305
30	23 5	267,000	105,000,000	11,000	2	14	37.4	0.98	0.09	.000	7,812	5,150	124
Tot'ls,	687.7	7,858,000	.....	223,600	49	301	609.6	...	...	...	.....	.....	.....
Av'gs.	22.9	262,000	106,000,000	7,500	1.6	10.0	20.3	0.54	0.08	.000	5,010	3,624	159

NOTES:—Percentage of Bacteria removed, 96.83.
Percentage of Filtrate used for washing, 2.8.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of May, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.5	267,000	105,000,000	10,900	2	15	36.5	0.96	...	.000	5,490	6,250	40
2	23.5	266,000	105,000,000	9,500	2	13	36.2	0.95	0.05	.000	4,380	3,300	56
3	23.5	266,000	105,000,000	10,900	2	13	37.9	1.00	0.03	.000	3,120	2,620	32
4	23.4	263,000	104,000,000	10,500	2	14	34.6	0.92	0.04	.000	4,090	2,120	36
5	23.5	267,000	105,000,000	9,700	2	13	35.6	0.93	0.05	.000	4,020	3,150	10
6	23.5	268,000	105,000,000	9,200	2	13	36.7	0.96	0.04	.000	3,350	2,100	11
7	23.5	268,000	105,000,000	10,100	2	13	36.9	0.96	0.04	.000	3,060	1,500	28
8	23.5	267,000	105,000,000	10,400	2	14	36.7	0.96	0.05	.000	4,720	2,520	35
9	23.5	269,000	106,000,000	10,900	2	14	35.6	0.93	0.17	...	13,500	11,400	103
10	23.4	267,000	106,000,000	11,400	2	15	37.1	0.97	0.28	.000	19,400	8,850	115
11	23.5	266,000	105,000,000	10,100	2	13	35.2	0.93	0.10	.000	8,100	5,070	120
12	23.5	267,000	105,000,000	10,200	2	13	26.1	0.68	0.05	.000	4,980	3,520	78
13	23.4	267,000	106,000,000	11,000	2	14	24.4	0.64	0.07	.000	4,310	3,000	63
14	23.5	268,000	105,000,000	10,100	2	13	24.2	0.63	0.04	.000	4,510	2,520	50
15	23.5	269,000	106,000,000	9,600	2	13	26.4	0.69	0.06	000	7,400	3,250	94
16	23.6	268,000	105,000,000	8,200	2	13	31.2	0.81	0.10	...	7,050	.....	130
17	23.6	269.000	105,000,000	11,800	2	15	55.5	1.44	0.20	...	33,600	16,300	770
18	23.5	269,000	106,000,000	11,200	2	15	66.6	1.73	1.20	.000	55,000	28,200	1,040
19	21 7	248,000	106,000,000	19,600	2	30	60.5	1.71	0.40	.000	17,000	9,000	73
20	22.8	257,000	104,000,000	16,700	3	23	48.0	1.31	0.18	.000	12,500	4,520	27
21	23.5	268,000	106,000,000	10,000	2	14	40.8	1.06	0.18	.000	12.700	6,400	85
22	22.5	257,000	106,000,000	10,400	2	14	53.2	1.45	0.55	.000	22,800	15,400	195
23	23.3	268,000	106,000,000	14,800	3	20	45.3	1.19	0.40	.000	13,200	5,400	200
24	23.1	267,000	107,000,000	15,000	3	20	41.4	1.09	0.15	.000	13,900	7,400	310
25	23.2	259,000	103,000,000	14,700	3	20	54.5	1.47	0.50	.000	19,500	11,600	125
26	22.2	273,000	114,000,000	20,500	4	29	45.0	1.15	0.31	.000	12,500	6,000	102
27	23.2	265,000	106,000,000	15,800	3	21	30.8	0.81	0.19	.000	6,400	3,890	125
28	23.2	267,000	106,000,000	15,400	3	20	25.5	0.67	0.11	.000	3,840	4,170	185
29	23.3	269,000	107,000,000	14,500	3	19	25.7	0.67	0.09	.000	3,410	3,670	285
30	23.5	272,000	107,000,000	9,700	2	13	28.9	0.74	0.10	.000	4,070	2,350	85
31	22.2	265,000	110,000,000	14,900	3	19	29.5	0.78	0 05	.000	1,500	1,600	42
Tot'ls,	720.6	8,246,000	.....	377,700	72	508	1182.5	...	...	...	.....	.....	.....
Av'gs,	23.2	266,000	106,000,000	12,200	2.3	16.4	38.1	1.00	0.19	.000	10,800	6,240	150

NOTES:—Percentage of Bacteria removed, 98.61.
Percentage of Filtrate used for washing, 4.6.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of June, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	16.5	189,000	106,000,000	4,600	1	6	5.9	0.22	0.07	.000	1,960	.....	23
2*	23.7	275,000	107,000,000	5,400	1	7	0.0	0.00	0.04	.010	1,700	1,100	580
3*	23.7	268,000	105,000,000	6,800	1	4	0.0	0.00	0.06	.012	1,420	1,270	420
4	23.1	263,000	105,000,000	15,100	3	21	148.4	3.95	0.04	.018	3,020	1,950	20
5	23.0	261,000	105,000,000	20,000	4	27	150.5	4.04	0.03	.000	2,300	175	4
6	22.0	252,000	106,000,000	19,300	4	25	72.2	2.01	0.02	...	3,540	1,350	5
7	23.0	264,000	106,000,000	19,200	4	24	72.3	1.92	0.02	.000	3,460	700	16
8*	23.7	269,000	105,000,000	6,400	1	8	0.0	0.00	0.02	.010	12,000	10,200	7,400
9*	24.0	264,000	102,000,000	0	0	0	0.0	0.00	0.02	.012	23,400	25,900	12,300
10*	24.0	274,000	106,000,000	0	0	0	0.0	0.00	0.02	.010	17,400	15,500	8,000
11*	23.7	269,000	105,000,000	8,300	1	11	0.0	0.00	0.02	.009	28,300	34,600	8,600
12	23.2	262,000	105,000,000	16,600	3	22	54.6	1.46	0.02	.000	19,500	17,300	700
13	23.2	261,000	104,000,000	15,700	3	20	49.4	1.33	0.02	...	12,400	12,200	60
14	22.3	253,000	105,000,000	27,100	3	43	40.7	1.13	0.03	.000	21,200	11,800	420
15	18.5	212,000	106,000,000	6,900	1	10	52.2	1.72	0.70	.000	27,900	17,200	86
16	23.1	265,000	106,000,000	22,000	3	29	62.3	1.65	0.80	.000	16,500	10,800	40
17	23.4	268,000	106,000,000	12,600	2	15	37.2	0.97	0.42	.000	7,650	4,420	63
18	23.3	267,000	106,000,000	11,800	2	16	25.9	0.68	0.21	.000	4,250	3,120	150
19	21.4	250,000	108,000,000	19,300	3	25	29.2	0.82	0.15	.015	6,150	5,000	225
20	23.5	274,000	108,000,000	10,700	2	17	53.2	1.36	0.40	.011	28,900	15,100	320
21	23.4	269,000	104,000,000	12,100	2	18	66.1	1.72	0.65	.012	25,100	12,300	185
22	23.2	273,000	109,000,000	12,700	2	19	84.8	2.17	0.70	.000	15,600	14 900	63
23	23.0	265,000	106,000,000	17,400	3	25	62.6	1.65	0.42	.000	5,950	3,870	9
24	22.7	249,000	101,000,000	31,300	4	49	60.9	1.71	0.23	.000	3,500	1,800	13
25	23.5	276,000	109,000,000	13,600	2	18	28.0	0.71	0.12	.000	2,700	2,570	91
26	22.8	266,000	108,000,000	25,700	4	34	46.6	1.23	0.12	.080	4,980	1,770	150
27	23.2	267,000	106,000,000	19,300	3	24	55.1	1.44	0.11	.000	.....	.....	88
28	23.2	266,000	106,000,000	17,700	3	22	31.0	0.82	0.07	.000	3,770	3,400	300
29	23.4	267,000	105,000,000	11,600	2	15	26.4	0.69	0.07	.000	6,250	4,470	510
30*	23.5	276,000	109,000,000	15,300	2	18	8.6	0.22	0.06	045	11,200	10,000	2,800
Tot'ls,	684.2	7,834,000	.....	424,500	69	572	1324.1	...	...	...	.....	.....	.....
Av'gs,	22.8	261,000	106,000,000	14,100	2.3	19.1	44.1	1.18	0.19	.008	11,100	8,750	1,450

NOTES:—Percentage of Bacteria removed, 86.90.
Percentage of Filtrate used for washing, 5.4.
During the 16 days ending 9.00 A. M. June 7, the filter was operated without trailing between washings.
* Omitting days starred, when for experimental purposes low quantities of coagulant or none at all were used, the average bacterial results were as follows:—River water, 10,300; effluent, 155; bacterial efficiency, 98.50 per cent.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of July, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.4	269,000	106,000,000	15,000	2	18	38.6	1.000	29.060		6,000	9,100	800
2	23.5	270,000	106,000,000	12,200	2	16	57.1	1.480	22.040		5,700	3,670	170
3	23 0	257,000	103,000,000	21,900	4	59	74 6	2.030	17.000		5,250	2,450	32
4	20.2	228,000	104.000,000	18,500	3	24	53.7	1.650	11	...	4,150	2,900	25
5	1.2	14,000	108,000,000	0	0	0	3.5	1.750	09	...	3,150	...	...
6	19.4	215,000	103,000,000	23,000	3	31	41.9	1.360	05	...	6,850	2,050	610
7	23.5	263,000	104,000,000	13,100	2	17	44.1	1.170	05.000		6,350	1,470	240
8	22.8	253,000	103,000,000	25,200	4	33	47.5	1.310	08.000		5,650	5,200	335
9	23.2	261,000	104,000,000	19,800	3	25	49.6	1.330	05.000		10,350	8,600	430
10	23.3	264,000	105,000,000	17,700	3	20	43.9	1.160	05.000		8,100	5,650	830
11	23.2	255,000	102,000,000	22,500	3	27	38.5	1.060	04	...	10,250	...	500
12	23.5	264,000	104,000,000	13,800	2	17	39.3	1.040	04.000		3,850	1,130	190
13	23.1	262,000	105,000,000	20,700	3	26	39.2	1.050	05.000		19,800	7,250	415
14	22.3	237,000	98,000,000	21,500	3	27	38.6	1.140	04.000		40,500	25,400	480
15	23.1	254,000	102,000,000	20,800	3	26	47.9	1.320	03.000		40,200	28,600	490
16	22.5	249,000	102,000,000	20,800	3	27	41.9	1.180	08.001		42,600	32,500	1,820
17	23.2	253,000	101,000,000	16,400	2	22	50.3	1.390	80.001		41,000	24,000	410
18	23.0	251.000	101,000,000	19,800	3	27	45.1	1.260	10.000		35,200	16,100	260
19	23.1	255,000	102,000,000	21,000	3	27	36.1	0.990	06.000		14,400	12,500	265
20	23.2	260,000	104,000,000	20,400	3	27	38.3	1.030	07.000		22,600	12,600	240
21	23.4	257,000	102,000,000	14,500	2	18	37.1	1.01	0.19.000		24,500	20,100	205
22	22.7	255,000	104,000,000	24,300	3	30	35.1	0.960	0.11 .000		20,800	14,800	130
23	22.7	255,000	104,000,000	23,900	3	30	40.4	1.110	05.000		15,200	7,700	50
24	23.3	261,000	104,000,000	14,700	2	19	36.0	0.970	03.000		8,050	3,120	59
25	23.4	247,000	98,000,000	13,000	2	16	54 7	1.550	0.06	...	14,600	11,800	78
26	23.0	255,000	103,300,000	20,500	3	27	55.6	1.530	06.000		8,750	4,650	67
27	22.8	251,000	102,000,000	22,100	3	27	59.2	1.650	09.000		16,500	5,900	65
28	22.8	249,000	101,000,000	20,100	3	26	50.1	1.410	06.000		24,500	14,400	910
29	23.1	254,000	102,000,000	20,200	3	26	63.4	1.750	05.000		18,500	9,650	45
30	23.2	262,000	104,000,000	20,200	3	25	62.8	1.680	05.045		17,700	11,000	115
31	23.2	258,000	103,000,000	19,500	3	25	59.5	1.610	06.060		20,100	12,300	52
Tot'ls,	687.3	7,638,000	.....	577,100	84	765	1423.6	...	...	...	.....	.....	.....
Av'gs,	22.2	246,000	103,000,000	18,600	2.7	24.7	45.9	1.31	0.11	.008	16,800	10,900	345

NOTES:—Percentage of Bacteria removed, 97.95.
Percentage of Filtrate used for washing, 7.6.

RECORD OF JEWELL MECHANICAL FILTER,

For the Month of August, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.			Washing.		Sulphate of Alumina Used.		Turbidity.		Bacteria Per Cubic Centimeter.		
		Total Passed.	Rate of Filtration Per Acre Daily.	Wash Water.	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Settled Water.	Effluent.
1	23.3	261,000	104,000,000	18,000	2	23	42.3	1.13	0.42	....	48,200	21,100	485
2	23.4	263,000	104,000,000	16,600	2	23	58.2	1.55	0.70	.000	27,500	14,000	185
3	23.4	257,000	102,000,000	15,400	2	20	52.5	1.43	0.35	.000	20,200	8,550	170
4	23.5	267,000	105,000,000	12,400	2	17	54.7	1.43	0	15.000	16,800	11,300	116
5	23.5	260,000	102,000,000	14,400	2	19	43.0	1.16	...	.000	22,300	12,400	710
6	23.4	260,000	103,000,000	13,200	2	18	48.4	1.30	0.80	.000	20,400	16,200	245
7	23.5	261,000	103,000,000	14,500	2	18	35.6	0.95	0.26	.000	9,300	8,000	190
8	23.1	259,000	104,000,000	23,000	3	26	36.7	0.99	0.37	.000	11,400	5,750	155
9	9.1	103,000	105,000,000	27,000	1	38	37.0	2.52	0.28	.000	49,400	2,720	400
10	23.6	263,000	103,000,000	11,000	1	13	68.8	1.83	0.92	.001	34,400	12,800	1250
11	23.7	260,000	101,000,000	9,700	1	12	54.4	1.46	0.55	.000	18,700	11,700	550
12	23.3	262,000	104,000,000	19,300	2	23	56.3	1.50	0.38	.000	9,550	4,870	160
13	22.8	260,000	105,000,000	16,800	2	20	40.6	1.09	0.31	.003	8,850	6,200	305
14	23.3	258,000	102,000,000	18,300	2	22	55.0	1.49	0.60	.000	15,500	13,700	280
15	23.4	266,000	105,000,000	15,100	2	18	59.1	1.55	0.24	...	10,300	4,920	96
16	23.4	265,000	105,000,000	18,100	2	22	42.8	1.13	0.12	.001	4,800	2,870	115
17	23.5	264,000	104,000,000	13,800	2	17	35.9	0.95	0.15	.000	6,450	4,850	250
18	23.7	266,000	104,000 000	8,100	1	9	29.9	0.79	0.08	.000	7,300	9,800	425
19	23.4	262,000	104,000,000	15,500	2	18	38.0	1.02	0.10	.000	10,800	5,750	260
20	23.4	264,000	104,000,000	18,400	2	21	54.5	1.45	0.30	.000	27,300	9,150	370
21	23.3	261,000	104,000,000	19,300	2	21	73.2	1.96	1.75	.000	25,000	19,800	540
22	23.0	257,000	103,000,000	25,600	3	31	63.6	1.73	0.50	.000	22,700	7,100	95
23	23.4	261,000	103,000,000	16,500	2	19	58.9	1.58	0.31	.000	12,600	8,250	65
24	23 4	261,000	103,000,000	14,800	2	17	57.6	1.54	0.26	.000	5,600	3,400	53
25	23.1	255,000	102,000,000	20,400	3	25	55.0	1.51	0.18	.000	6,450	3,120	37
26	23.4	261,000	103,000,000	14,100	2	16	44.5	1.19	0.10	.000	1,920	1,620	130
27	23.5	262,000	103,000,000	15,200	2	18	45.2	1.21	0.09	.000	3,500	2,750	85
28	23.5	264,000	104,000,000	8,600	1	9	36.8	0.98	0.18	.000	5,020	3,500	94
29	23.5	256,000	101,000,000	15,900	2	18	40.0	1.09	0.10	...	3,020	2,550	110
30	23.4	256,000	101,000,000	14,500	2	17	53 9	1.47	0.09	.000	1,700	1,400	65
31	21.5	237,000	102,000,000	16,900	3	37	48.6	1.43	0.09	.000	1,520	1,150	39
Tot'ls,	708.7	7,912,000	.....	500,400	61	625	1521.0	...	...	...	.....	.....	...
Av'gs,	22.9	255,000	103,000,000	16,100	2.0	20.2	49.1	1.35	0.36	.000	15,100	7,780	260

NOTES:—Percentage of Bacteria removed, 98.28.
Percentage of Filtrate used for washing, 6.3.
Filter cleansed,—100 pounds of Soda Ash used with steam.

CHAPTER V.

WORMS TILE FILTER EXPERIMENTS.

Description.

Water purification by the Worms Tile Filter was carried out in two separate and distinct stages. The first by coagulation, sedimentation, and crude filtration, and the second by filtration through tiles. Two iron tanks were used, each of which was subdivided by a plate partition. This gave us two systems, alike, but independent of each other. All details and arrangements of this system were as suggested by the company controlling the patent rights and are shown upon Plates No. 19 and No. 20, opposite page 204.

In the first test, extending from November 25, 1897, to April 9, 1898, two different methods were tried. In one battery the applied water was coagulated, as well as settled, by the addition of ferric chloride, and in the other the water was simply settled, before passing to the filter tank. In each case the water was metered as it entered the tanks. In the second test, extending from June 12 to August 27, 1898, the applied water was treated with coagulant before passing to each battery. One meter and feeding device for coagulant answered for both sets of tiles, the treated and metered water being equally divided.

Coagulating Solution and Apparatus.

The coagulant used in the first experiments was a solution of perchloride of iron, having a specific gravity of 1.25. This stock solution was further diluted with water for use, and the specific gravity reduced to 1.07. After the plant was remodeled and during the second test a different coagulant was used. The new solution was made by dissolving an iron ore in 15° Baume muriatic acid. This solution was prepared in small quantities, as required. The ore contained 64.7 per cent. of oxide of iron, 1.78 per cent. of carbonate of lime, 9.87 per cent. of silica, and 23.65 per cent. of water. About two per cent. of the total iron was present as ferrous oxide, the remainder being ferric oxide. The solution, which was a thick, muddy mixture, was added, drop by drop, to the water as it flowed from the meter into the first tank.

The dropping apparatus consisted of three glass bottles. The lower one held the iron solution and the other two were reservoirs for water and air, respectively. They were so arranged that a drop of water, falling from the first into the second, displaced an equal volume of air, which in turn caused a drop of the iron solution to fall into the water.

Scrubbers.

Settling Tanks, No. 3 and No. 4, designated as "Scrubbers," were the ones in which the first step toward purification was carried out.

These tanks contained, beginning at the bottom, a layer of bricks, placed on edge about one inch apart, with the open channels converging towards the outlet. On top of these bricks a six-inch layer of coarse stone, the size of ordinary ballast, was placed. Next eighteen inches of screenings, then six inches of gravel, ranging in size from one-quarter to one-half inch in diameter, and finally, three inches of ballast, completed the scrubber. The capacity to the overflow, was 770 gallons. The function of this part of the system, as stated by the filter company, "was to remove all suspended matter to such an extent, that the water delivered to the tiles should be clear and transparent; also, to remove bacteria to such a degree, that less than 100 per cubic centimeter would remain in the water applied to the tiles." From the bottom of the scrubber, a three-inch pipe carried the water into the top of the filter tank.

Filter Tanks and Tiles.

In the filter tank the final step in the purification was accomplished. This tank contained the artificial sandstone tiles, connected with piping, fittings and the valves and gates, necessary for their operation.

The tiles were made in Germany and shipped direct for the purpose of these experiments. They were composed of sand and ground glass mixed and baked in a mould at about the melting point of glass. In the center of each tile was an open chamber, of about 0.50 cubic foot capacity, into which the filtered water passed.

The effluent from each tile fell, without interruption, into a glass cylinder, named the indicator, three inches in diameter, and fifteen inches high, with a bottom of brass plate one-eighth inch thick. In the center of this plate there was a standard orifice, 0.376 inch in diameter, and a scale on the side of the indicator showed directly the rate of flow in "Gallons per Twenty-four Hours."

Washing.

The filter was washed by a reverse current from an iron tank, holding 350 gallons; the high water elevation of which was 19.5 feet above the centers of the tiles. This tank was connected to each tile and to the scrubbers and was filled by pumping the effluents from the tiles. Sometimes more wash water was required than the tiles would supply and in such cases the effluents from the sand filters were used.

When the condition of the water passing from the scrubber became poor, contained flocks, or was turbid; or, when the scrubber became so clogged that it did not supply sufficient water for the tiles, its life was renewed by washing. The inlet and coagulant feed were shut off and a reverse current of filtered water, from the overhead tank, passed through for a few minutes. This was supplemented by washing with a small hose stream of sand-filtered water. When the scrubber was first put

into service after washing, the rate of inlet water was about 1,300 gallons per tile for twenty-four hours. This rate was gradually increased to the usual amount, of 1,850 gallons, and the scrubber used until it again became clogged, when the process was repeated.

To wash a tile, the gate connecting the tile with the overhead tank was opened cautiously and a reverse current of water allowed to pass through the tile. In the earlier experiments it was customary to use one tank full, 350 gallons, for each tile. In the later tests, however, only one-half a tank full was used for each tile. The rate of flow was about 130 gallons per minute.

Operations.

The successful operation of the Tile Filter depended so largely upon the correct addition of the coagulant that almost constant attention was necessary. The amount of iron solution was varied from thirty to eighty drops per minute, according to the condition of the applied water; very slight change in the turbidity necessitating a readjustment of the dropper. The water, after being treated with the iron solution and after passing through the scrubber, was required to be almost without opalescence, in order that the effluent from the tiles should be clear. The nicety of this adjustment can be better appreciated when it is considered that, up to a certain point, which varied with the condition of the applied water, the addition of the iron solution would cause a decided improvement. When the proper end point was reached, no opalescence could be detected in the water so treated. If, however, a little more iron was added, not only was the iron solution wasted, but the water so treated became again opalescent.

The water in the filter tank, in the first experiment, was always kept at a constant level at the height of the overflow, which gave a head of 2.5 feet on the effluent pipes. In the second test the maximum head permitted was 0.9 foot. In the first instance the effluent valves were regulated so that a constant rate was obtained, as the loss of head increased. In the second case, the valves were left wide open and the head in the tank gradually increased to the maximum, as the loss of head increased. As the process of filtration proceeded, the loss of head, which represented the clogging of the tiles, became greater and greater, until a point was reached when practically no water passed through. In actual practice, however, washing was resorted to before this point was reached.

Breakage of Tiles.

Great care was taken in opening the wash gates, so that a sudden rush of water was avoided. Tiles were frequently broken, however, while washing; in fact, during the last week of the first test, we used only one tile, and we should have been obliged to stop the experiments with

Water Reservoir
3" Water
Air Reservoir
Coagulant Reservoir
Meter

WOR

this system, had not new tiles been furnished. It was possible that air collected in the wash piping system which gave an opportunity for a water hammer when the gate was opened, and caused the trouble. This piping was changed, however, July 21, 1898, to overcome this difficulty, and yet after this, two tiles were broken. All the breakage occurred when the tiles had been in use some time and when they had become somewhat clogged. It was noticed that, with the continued use of the tiles, the passage of the water through them became less free, and their bacterial efficiency increased. It is probable, therefore, that the clogging was of a permanent nature, and reduced the size of the passages, and, with this increasing obstruction, the pressure inside the tiles at the time of washing became greater, hence the breaking. As it was, the tiles were broken at about the time when satisfactory bacterial results commenced to be obtained.

The following table gives the dates when tiles were broken:—

Calendar Date.	Tile.
January 11, 1898	F.
" 20, "	D.
February 15, "	E.
March 22, "	C.
April 4, "	A.

Of the new tiles, which were put in when the plant was reconstructed, tiles D and E were broken July 15; C on August 15, and B on August 27, 1898.

BACTERIAL EFFICIENCY AFTER WASHING.

The bacterial efficiency of the tiles after washing is less than at other times, as is shown by the following results, selected for this purpose:—

TABLE A.

Bacteria in Effluent from Worms Tile Filter, at Times of Washing.

Test with Tile B. Calendar Date, August 26, 1898. Time.	Bacteria Per C C.	Remarks.	Test with Tile E. Calendar Date, August 27, 1898. Time.	Bacteria Per C. C.	Remarks.
3.18 P. M.	11	V. S.	3.15 A. M.	7	V. S.
4.18 "	494	V. S.	4.18 "	88	V. O.
4.21 "	945		4.21 "	112	
4.24 "	483		4.24 "	87	
4.28 "	242		4.28 "	56	
4.38 "	115		4.38 "	44	
4.48 "	77		5.18 "	57	
5.18 "	33		7.18 "	102	
7.19 "	15		9.20 "	77	
11.20 "	20				

NOTES:—V. S., means Effluent Valve Closed before Washing.
V. O., means Effluent Valve Opened after Washing.

It will be seen that the numbers are low just previous to washing and that they were largely increased after this process. After washing, the high numbers usually extended over a period, not exceeding half an hour, after which the tile reached its normal efficiency. It will be found, however, that when the number of bacteria was 100 per cubic centimeter, or less, a corresponding decrease in the quantity of filtered water took place.

Tabulation of Results.

On the following pages are tables showing the daily results, from this filter, secured in both tests. Only the bacterial results are given for the first test and for the first month of the second. The last two tables give the entire results secured during the months of July and August, 1898. The results of chemical analyses are given in Appendix No. 2, page 265 et seq.

BACTERIAL RESULTS,—WORMS TILE FILTER,

For the Month of December, 1897.

Date. 24 Hours Ending 9.00 A. M.	Bacteria Per Cubic Centimeter.								
	Applied Water.	Settled Water.		Tile A.	Tile B.	Tile C.	Tile D.	Tile E.	Tile F.
		With Coagulant. Tank No. 3.	Without Coagulant. Tank No. 4.						
1	36,000	36,000	.....	75,000	31,150	36,750	32,200	33,600	33,600
2	23,300	4,200	26,500	11,550	14,300	12,600	13,700	18,900	19,200
3	17,900	12,800	22,300	21,700	6,250	6,050	6,350	8,650	5,000
4	17,250	8,000	8,150	8,300	4,950	4,850	4,100	5,700	8,250
5	11,450	5,600	12,500	3,900	3,600	4,250	6,250	9,400	3,800
6	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	28,850	24,850	19,950	12,410	8,025	7,825	6,975	4,600	6,550
8	24,400	14,225	19,250	9,700	6,300	6,725	5,600	9,700	6,675
9	20,050	14,050	31,150	11,750	13,350	13,900	5,450	5,450	4,150
10	21,100	13,660	27,550	5,950	7,550	7,238	3,088	3,175	2,825
11	25,700	.....	.....	.....	.....	.....	.....	.....	.....
12	8,025	3,675	10,700	2,200	2,150	7,917	9,950	.....	.....
13	16,400	.....	.....	.....	.....	.....	.....	.....	.....
14	7,800	8,200	5,750	2,087	1,537	2,825	1,637	925	1,237
15	7,975	4,800	6,000	2,450	1,725	4,250	1,700	1,125	850
16	15,400	11,375	11,800	7,663	2,700	3,350	2,963	1,800	1,690
17	25,475	17,750	22,050	5,500	5,850	6,575	4,025	4,675	4,350
18	16,350	9,150	11,350	3,875	3,663	4,575	4,158	2,263	2,963
19	11,800	4,000	.....	1,250	2,000	2,600	1,650	1,650	2,300
20	13,700	3,675	8,000	1,338	2,400	3,175	1,987	1,988	2,263
21	.....	.....	.....	.....	.....	.....	.....	.....	.....
22	.....	.....	.....	.....	.....	.....	.....	.....	.....
23	13,050	6,975	13,050	3,800	3,138	3,862	3,187	4,450	3,487
24	7,650	4,675	5,950	1,850	1,825	2,763	2,712	3,150	2,575
25	5,025	4,550	3,800	1,813	2,025	1,925	1,662	2,275	1,487
26	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	2,500	850	2,550	1,050	800	775	1,125	925	750
28	2,750	2,775	2,600	850	1,575	1,202	1,025	1,137	913
29	1,900	700	3,000	1,150	1,088	850	625	837	625
30	4,000	.....	3,800	1,900	2,475	1,050	1,062	1,900	1,075
31	3,900	3,225	4,300	1,262	1,563	1,250	1,613	2,138	1,650
Av'gs,	14,433	9,157	12,263	8,012	5,280	5,965	4,992	5,434	4,928
Percentages of Bacteria removed...		36.6	15.0	44.5	63.4	58.7	65.4	62.3	65.9

BACTERIAL RESULTS,—WORMS TILE FILTER,

For the Month of January, 1898.

Date. 24 Hours Ending 9.00 A. M.	Bacteria Per Cubic Centimeter.								
	Applied Water.	Settled Water.		Tile A.	Tile B.	Tile C.	Tile D.	Tile E.	Tile F.
		With Coagulant. Tank No. 3.	Without Coagulant. Tank No. 4.						
1	2,000	1,250	1,650	575	625	825	875	1,875	975
2	4,150	850	3,225	500	388	537	950	1,167	725
3	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	1,625	1,350	2,200	800	375	500	700	1,575	400
5	3,675	1,625	3,250	787	480	375	1,175	1,775	938
6	3,125	3,350	3,500	1,287	1,450	1,325	1,950	1,675	1,000
7	3 950	2,675	2,900	1,237	800	1,150	1,987	2,087	1,763
8	8.675	2,125	13,600	1,250	1,375	1,200	3,275	2,450	2,625
9	21,500	1,875	23,700	825	1,075	975	4,350	3,500	3,275
10	12,550	.....	.....	.....	.....	.....	.....	.....	.....
11	16,175	1,950	.....	1,000	1,100	800	5,687	5,650	3,037
12	11,375	1,825	.....	425	775	537	4,550	3,650	3,800
13	16,125	5,300	.....	1,152	850	837	4,900	2.537	.....
14	30,987	4,200	.....	1,200	2,000	1,625	9,150	4,850	.....
15	40,350	15,750	.....	2,925	3,325	2,875	8,150	8,450	.....
16	45,325	26,300	.....	14,900	11,725	14,200	13,500	16,800	.....
17	.....	....	.....	.....	.....	.....	.....	.....	.....
18	21,275	16,000	.....	4,600	6,050	6,100	16,075	7,600	.....
19	22,700	10,600	.....	2,650	3,875	3,275	19,600	7,250	.....
20	11,000	8,050	.....	2,625	3,575	3,250	13,500	2,725	.....
21	12,300	6,600	.....	2,950	1,800	2,575	7,450	3,150	.....
22	19,000	3,950	.....	1,500	875	1,225	.....	3,075	.....
23	20,450	13,600	.....	4,850	6,850	5,250	.....	4,450	.....
24	23,750	.....	.....	.....	.....	.....	.....	.....	.....
25	26,150	24,100	.....	11,700	12,775	.....	.....	7,300	.....
26	12,650	15,400	.....	4,900	7,150	.....	.....	5,750	.....
27	15,000	12,100	.....	4,400	3,500	.....	.....	3,425	.....
28	14,050	10,200	.....	7,200	8,700	.....	.....	1 800	.....
29	6,825	6,500	.....	2,500	5,300	.....	.....	1 575	.....
30	2,600	2,150	.....	700	675	.....	.....	875	.....
31	.....	.....	.....	.....	.....	.....	.....	.....	.....
Av'gs,	15,333	7,680	.....	3,055	3,364	2,472	6,546	4,116	.....
Percentages of Bacteria removed...		49.9	.....	80.1	78.1	83.9	57.3	73.2	.....

BACTERIAL RESULTS,—WORMS TILE FILTER,

For the Month of February, 1898.

Date. 24 Hours Ending 9.00 A. M.	Bacteria Per Cubic Centimeter.								
	Applied Water.	Settled Water.		Tile A.	Tile B.	Tile C.	Tile D.	Tile E.	Tile F.
		With Coagulant. Tank No. 3.	Without Coagulant. Tank No. 4.						
1	2,350	400	.....	.....	800	275	.....	550	.....
2	2,250	900	.....	658	537	675	.....	650	.....
3	2,775	.....	.....	.....	875	1,375	.....	900	.....
4	2,700	2,050	.....	1,400	375	725	.....	725	.....
5	1,575	1,550	.....	800	800	625	.....	750	.....
6	1,425	1,950	.....	350	625	600	.....	350	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	1,700	300	.....	375	450	525	.....	300	.....
9	3,550	1,250	.....	475	277	350	.....	850	.....
10	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	8,025	1,300	.....	50	200	425	.....	.....	.....
13	17,500	1,800	.....	575	275	500	.....	1,125	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	25,600	200	.....	425	126	525	.....	.....	.....
16	24,150	6,100	.....	1,000	375	5,550	.....	.....	.....
17	23,600	5,800	.....	125	1,025	350	.....	.....	.....
18	9,250	4,300	.....	350	613	525	.....	.....	.....
19	11,025	2,450	.....	500	850	700	.....	.....	.....
20	7,050	1,900	.....	205	425	500	.....	.....	.....
21	.....	.....	.....	.....	.....	.....	.....	.....	.....
22	12,025	2,200	.....	350	325	675	.....	.....	.....
23	10,150	2,350	.....	875	750	625	.....	.....	.....
24	12,350	13,000	.....	2,250	4,625	3,575	.....	.....	.....
25	9,400	3,050	.....	125	300	325	.....	.....	.....
26	12,112	5,150	.....	600	675	500	.....	.....	.....
27	7,750	5,300	.....	825	1,175	650	.....	.....	.....
28	8,600	9,200	.....	3,175	1,975	3,076	.....	.....	.....
Av'gs,	9,430	3,295	.....	738	802	1,028	.....	.....	.....
Percentages of Bacteria removed...		65.1	.....	92.17	91.50	89.10	.....	.....	.....

BACTERIAL RESULTS,—WORMS TILE FILTER,

For the Month of March, 1898.

Date. 24 Hours Ending 9.00 A. M.	Bacteria Per Cubic Centimeter.								
	Applied Water.	Settled Water.		Tile A.	Tile B.	Tile C.	Tile D.	Tile E.	Tile F.
		With Coagulant. Tank No. 3.	Without Coagulant. Tank No. 4.						
1	6.125	7,150	.....	5,150	2,675	6,500	.....	.....	.....
2	7,650	4,600	.....	.....	2,025	2,775	.....	.....	.....
3	7,450	3,800	.....	521	560	636	.....	.....	.....
4	4,925	2,650	.....	628	749	868	.....	.....	.....
5	4,475	1,300	.....	182	266	220	.....	.....	.....
6	5,150	2,750	.....	161	253	400	.....	.....	.....
7	3,400	.....	.....	.....	.....	.....	.....	.....	.....
8	5,100	4,100	.....	.....	231	148	.....	.....	.....
9	5,075	1,500	.....	169	246	470	.....	.....	.....
10	5,175	7,000	.....	198	209	281	.....	.....	.....
11	5,700	2,750	.....	79	107	246	.....	.....	.....
12	5,475	6,100	.....	.....	.....	200	.....	.....	.....
13	6,525	1,850	.....	54	84	107	.....	.....	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	12,025	2,650	.....	110	70	174	.....	.....	.....
16	14,175	5,000	.....	150	90	270	.....	.....	.....
17	12,400	3,000	.....	.....	110	175	.....	.....	.....
18	7,350	1,650	.....	150	122	175	.....	.....	.....
19	8,600	6,700	.....	285	191	480	.....	.....	.....
20	9,900	... ..	.....	72	.....	86	.....	.....	.....
21	.....	.....	.....	.....	.....	.....	.....	.....	.....
22	.....	.....	.....	.....	.....	.....	.....	.....	.....
23	56,000	.....	.....	.....	.....	.....	.....	.....	.....
24	55,483	33,250	.....	301	4,660	.....	.....	.....	.....
25	23,267	4,550	.....	546	1,022	.....	.....	.....	.....
26	14,400	1,600	.....	170	178	.....	.....	.....	.....
27	7,000	3,250	.....	166	102	.....	.....	.....	.....
28	4,800	.....	.....	.....	.....	.....	.....	.....	.....
29	4,750	400	.....	107	137	.....	.....	.....	.....
30	9 967	5,200	.....	151	133	.....	.....	.....	.....
31	16,583	2,150	.....	420	332	.....	.....	.....	.....
Av'gs,	11,747	4,790	.....	465	633	789	.....	.....	.....
Percentages of Bacteria removed...		59.2	.....	96.04	94.61	93.28	.....	.....	.....

BACTERIAL RESULTS,—WORMS TILE FILTER.

For the Month of June, 1898.

Date. 24 Hours Ending 9.00 A. M.	Bacteria Per Cubic Centimeter.								
	Applied Water.	Settled Water with Coagulant.		Tile A.	Tile B.	Tile C.	Tile D.	Tile E.	Tile F.
		Scrubber No. 3.	Scrubber No. 4.						
1	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	....	.....	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	12,400	530	670	905	1,260	720	1,530	1,070	1,120
14	21,200	690	680	525	840	395	450	540	550
15	27,900	275	1,030	870	1,030	810	930	670	710
16	16,500	570	305	960	1,000	600	910	820	1 080
17	7,650	210	190	580	850	525	660	550	550
18	4 250	620	105	1,670	820	890	800	990	790
19	6,150	240	380	1,340	330	1,990	770	560	1,010
20	28,900	380	810	2,730	290	1,130	1,110	900	900
21	25,100	640	750	520	385	260	405	690	395
22	15,600	255	350	260	95	110	365	270	140
23	5,950	72	65	255	25	88	170	175	52
24	3,500	160	120	79	20	34	38	72	12
25	2,700	59	94	79	82	106	30	39	150
26	4,980	65	140	440	210	120	160	75	61
27	.....	...	...	220	270	240	125	190	205
28	3,770	120	420	330	285	275	290	335	205
29	6,250	280	235	200	280	215	135	140	140
30	11,200	600	680	395	405	465	355	395	350
Av'gs,	12,000	339	413	687	471	498	513	471	468
Percentages of Bacteria removed....		97.18	96.56	94.28	96.08	95.85	95.73	96.08	96.10

RECORD OF WORMS TILE FILTER,

For the Month of July, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.				Washing.		Iron Ore Used.		Turbidity.		Bacteria Per Cubic Centimeter.				
		Tiles.			Total Wash Water	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Scrubber No. 3.	Tiles.		
		A	B	C										A	B	C
1	21.0	1,200	1,740	1,560	340	1	4	10.2	7.4	0.29	.000	6,000	415	110	185	200
2	20.4	980	2,010	1,580	300	1	4	5.2	4.2	0.22	.010	5,700	610	280	330	340
3	18.8	980	1,650	1,420	650	2	15	5.7	5.4	0.17	.007	5,250	240	160	150	155
4	23.3	980	2,250	1,810	320	1	6	3.8	2.8	0.11	.....	4,150	87	195	.....	.....
5	21.8	880	1,980	1,680	600	2	14	4.5	3.3	0.09	.....	3,150	76	135	60	70
6	20.3	840	1,870	1,200	690	2	17	5.5	4.9	0.05	.....	6,850	230	250	770	250
7	21.2	910	2,000	1,550	620	1	7	4.8	3.3	0.05	.000	6,350	1,120	740	1,070	860
8	23.2	940	2,010	1,720	300	1	5	5.1	3.6	0.08	.000	5,650	540	240	320	250
9	20 9	840	1,580	1,390	660	2	13	5.7	4.9	0.05	.000	10,350	435	125	91	125
10	22.6	950	1,920	1,600	660	2	14	5.0	3.6	0.05	.000	8,100	790	420	495	315
11	23.8	1,190	1,990	1,670	0	0	0	5.6	3.9	0.04	.....	10,250	102	240	230	305
12	20.8	1,010	1,610	1,450	950	3	8	3.8	2.8	0.04	.000	3,850	650	275	290	205
13	22.7	1,020	1,820	1,600	630	2	3	4.1	2.9	0.05	.000	19,800	1,140	355	710	540
14	22.9	1,110	1,930	1,590	680	2	9	3.7	2.7	0.04	.000	40,500	2,960	970	1,290	970
15	20.9	1,000	1,690	1,480	640	2	9	6.2	4.5	0.03	.000	40,200	2,250	550	740	710
16	21.0	1,030	1,830	1,500	0	0	0	3.0	3.5	0.08	.001	42,600	1,910	345	340	320
17	0 0	0	0	0	0	0	0	0.0	0.0	0.80	.....	41,000	.....	.....	.....	.....
18	8.2	380	590	540	280	1	7	1.7	7.9	0.10	.....	35,200	.....	465	390	460
19	22.6	950	1,670	1,430	630	2	8	1.8	3.2	0.06	.000	14,400	680	220	185	150
20	2.8	130	240	200	0	0	0	0.4	4.5	0.07	.000	22,600	1,050	600	435	280
21	12.8	550	1,020	690	0	0	0	1.7	5.2	0.19	.....	24,500	1,300	325	415	385
22	20.0	970	2,100	1,700	810	2	16	3.6	3.0	0.11	.000	20,800	3,020	500	680	820
23	20.8	1,060	2,210	1,800	480	1	7	4.1	2.8	0.05	.000	15,200	550	220	195	220
24	20.6	1,060	2,160	1,730	890	1	8	3.6	2.5	0·03	.000	8,050	92	94	68	101
25	20.2	960	2,200	1,670	730	2	14	4.0	2.7	0.06	.....	14,600	345	130	235	190
26	20.6	950	1,910	1,960	820	1.7	10	4.4	3.0	0.06	.000	8,750	310	100	110	130
27	19.4	1,030	1,990	1,700	910	1.3	14	3.4	2.5	0.09	.000	16,500	870	180	295	250
28	22.1	1,100	2,340	1,930	470	1	6	3.9	2.5	0.06	.000	24,500	1,310	240	320	790
29	20.2	990	1,940	1,720	1,210	3	17	4.2	3.0	0.05	.000	18,500	1,690	410	580	1,140
30	21.4	1,030	2,110	1,850	770	2	11	3.8	2.6	0.05	.000	17,700	1,160	275	415	340
31	21.5	1,140	2,030	1,850	920	2	11	3.6	2.4	0.06	.000	20,100	740	120	145	115
Totals,	598.8	28,140	54,390	45,570	16,900	44	257	126.1	....	.....	.....	.....	.....	.....	.....	.....
Av'gs,	19.3	910	1,750	1,470	550	1.4	8.3	4.1	3.6	0.11	.001	16,800	920	310	400	375
Percentages of Bacteria removed.....													94.52	98.16	97.62	97.77

RECORD OF WORMS TILE FILTER,

For the Month of July, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.				Washing.		Iron Ore Used.		Turbidity.		Bacteria Per Cubic Centimeter.				
		Tiles.			Total Wash Water	Number of times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Scrubber No. 4.	Tiles.		
		D	E	F										D	E	F
1	22.9	1,490	1,570	2,030	.....	0	0	10.1	7.4	0.29	.000	6,000	365	160	110	170
2	20.2	1,140	1,180	1,870	300	1	4	5.2	4.2	0.22	.010	5,700	365	200	145	210
3	17.5	1,030	850	1,580	260	1	4	5.7	5.4	0.17	.007	5,250	210	245	130	160
4	23.3	1,160	1,270	2,110	320	1	8	3.8	2.8	0.11	....	4,150	195	235	215	270
5	22.7	1,660	1,070	2,130	0	0	0	4.5	3.3	0.09	....	3,150	210	140	46	74
6	18.0	1,150	910	1,870	620	2	14	5.5	4.9	0.05	....	6,850	295	780	680	1,320
7	23.4	1,800	1,480	2,400	330	1	6	4.8	3.3	0.05	.000	6,350	680	590	510	730
8	23.3	1,620	1,330	2,180	330	1	7	5.1	3.6	0.08	.000	5,650	425	240	235	280
9	20.8	1,310	1,130	1,920	650	2	14	5.7	4.9	0.05	.000	10,350	790	250	280	330
10	23.4	1,590	1,360	2,400	320	1	5	5.0	3.6	0.05	.000	8,100	790	455	300	425
11	21.9	1,510	1,420	2,040	980	3	10	5.6	3.9	0.04	....	10,250	460	345	415	510
12	22.5	1,730	1,410	2,180	310	1	3	3.8	2.8	0.04	.000	3,850	265	120	130	160
13	23.3	2,750	940	1,760	0	0	0	4.1	2.9	0.05	.000	19,800	1,290	1,180	730	660
14	22.2	2,520	1,030	1,580	310	1	3	3.7	2.7	0.04	.000	40,500	7,050	5,030	1,910	1,640
15	23.2	2,410	1,120	1,900	0	0	0	6.2	4.5	0.03	.000	40,200	1,670	1,460	570	580
16	6.6	740	300	520	0	0	0	3.0	3.5	0.08	.001	42,600	790	1,080	210	570
17	0.0	0	0	0	0	0	0	0.0	0.0	0.80	....	41,000	.....	....	.....	....
18	0.0	0	0	0	0	0	0	1.7	7.9	0.10	....	35,200	.....	....	.....	....
19	0.0	0	0	0	0	0	0	1.8	3.2	0.06	.000	14,400	.....	....	.....	....
20	0.0	0	0	0	0	0	0	0.4	4.5	0.07	.000	22,600	.....	....	.....	....
21	0.0	0	0	0	0	0	0	1.7	5.2	0.19	....	24,500	.....	....	.....	....
22	17.9	1,530	1,440	810	430	1	10	3.6	3.0	0.11	.000	20,800	2,170	5,800	11,400	3,420
23	22.3	2,310	2,210	650	350	1	12	4.1	2.8	0.05	.000	15,200	350	800	1,230	295
24	23.4	2,050	2,000	1,230	610	1	10	3.6	2.5	0.03	.000	8,050	415	490	530	310
25	23.5	2,360	2,190	1,080	0	0	0	4.0	2.7	0.06	....	14,600	295	970	610	160
26	22.5	2,350	2,240	800	300	1	8	4.4	3.0	0.06	.000	8,750	265	365	1,640	110
27	20.5	2,180	1,780	890	840	2	14	3.4	2.5	0.09	.000	16,500	2,150	910	520	380
28	24.0	2,720	2,170	840	0	0	0	3.9	2.5	0.06	.000	24,500	750	750	620	175
29	21.7	2,370	2,030	800	320	1	6	4.2	3.0	0.05	.000	18,500	680	1,050	455	250
30	22.6	2,160	1,900	1,190	450	1	6	3.8	2.6	0.05	.000	17,700	3,010	1,570	1,080	840
31	24.0	2,250	2,090	1,130	0	0	0	3.6	2.4	0.06	.000	20,100	330	375	200	1,400
Totals,	557.6	47,890	38,420	39,890	8,030	23	144	126.0	....	.....	.....	.....	.....	....	.....	....
Av'gs,	18.0	1,540	1,240	1,290	260	0.7	4.6	4.1	3.6	0.11	.001	16,800	1,010	980	960	590
Percentages of Bacteria removed.....													93.99	94.17	94.29	96.49

RECORD OF WORMS TILE FILTER,

For the Month of August, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.				Washings.		Iron Ore Used.		Turbidity.		Bacteria Per Cubic Centimeter.				
		Tiles.			Total Wash Water	Number of Times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Scrubber No. 3.	Tiles.		
		A	B	C										A	B	C
1	22.2	1,150	2,240	1,910	460	1	5	5.4	3.6	0.42	....	48,200	450	61	72	76
2	19.3	910	1,900	1,720	1,260	3	18	4.2	3.0	0.70	.000	27,500	520	130	190	165
3	12.9	650	1,200	1,100	890	3	14	6.5	7.4	0.35	.001	20,200	650	66	125	104
4	16.0	810	1,450	1,340	1,360	4	20	6.2	5.9	0.15	.000	16,800	640	72	125	130
5	14.7	790	1,410	1,260	580	2	8	9.6	10.5	....	.000	22,300	190	220	130	160
6	7.2	380	590	610	1,310	4	19	5.3	10.8	0.80	.002	20,400	.....	34	34	29
7	16.9	830	1,500	1,440	870	2	12	4.8	3.9	0.26	.001	9,300	410	53	103	76
8	19.5	950	1,610	1,840	450	1	5	5.9	4.7	0.37	.000	11,400	155	35	16	43
9	18.4	900	1,780	1,670	740	2	11	7.1	5.7	0.28	.001	49,400	325	93	190	105
10	21.6	1,170	2,230	1,920	440	1	5	9.0	6.2	0.92	000	34,400	210	91	106	31
11	10.6	460	880	760	1,780	5	29	4.2	5.4	0.55	.001	18,700	170	84	99	77
12	20.0	940	1,730	1,550	920	2	12	5.1	4.3	0.38	.000	9,550	105	49	55	44
13	22.6	1,130	2,090	1,890	460	1	6	4.8	3.4	0.31	.006	8,850	50	13	17	16
14	17.7	780	1,360	1,260	1,640	4	22	5.0	4.4	0.60	.001	15,500	195	22	38	49
15	20.3	960	1,550	1,420	1,250	3	17	5.4	4.3	0.24	....	10,300	305	26	37	24
16	7.4	280	380	390	1,210	3	18	3.8	8.2	0.12	.001	4,800	400	36	57	30
17	7.9	450	680	.....	2,220	5	27	2.6	4.2	0.15	....	6,450	500	100	100	....
18	21.3	1,270	2,090	.....	910	3	11	4.3	3.2	0.08	.000	7,300	540	180	315	....
19	21.1	1,310	2,150	.....	1,200	4	15	2.2	1.7	0.10	.000	10,800	940	480	510	....
20	11.5	730	1,170	.....	910	3	12	4.2	6.0	0.30	.000	27,300	960	560	690	....
21	13.6	480	870	.....	1,380	3	17	4.5	8.6	1.75	.010	25,000	105	43	18	....
22	23.0	900	1,830	.....	280	1	4	4.1	4.1	0.50	.010	22,700	180	26	25	....
23	21.0	740	1,450	.....	950	3	12	4.5	5.4	0.31	.000	12,600	88	31	33	....
24	19.1	820	1,570	.....	590	2	8	4.2	5.2	0.26	.000	5,600	78	45	46	....
25	21.1	910	1,620	.....	1,000	3	12	3.9	4.3	0.18	.000	6,450	295	20	18	....
26	20.6	750	1,470	.....	1,050	3	12	2.4	3.0	0.10	.000	1,920	345	41	54	....
27	16.9	620	1,250	.....	830	3	12	3.0	4.1	0.09	.000	3,500	115	52	74	....
28	....	.....	.....	.....	.....	...	....	....	....	....	....	.....	.....	....	....	....
29	....	.....	.....	.....	.....	...	....	....	....	....	....	.....	.....	....	....	....
30	....	.....	.....	.....	.....	...	....	....	....	....	....	.....	.....	....	....	....
31	....	.....	.....	.....	.....	...	....	....	....	....	....	.....	.....	....	....	....
Totals,	464.4	22,070	40,030	22,080	26,940	74	363	132.2	....	...	....	.....	.....	....	....	....
Av'gs,	17.2	820	1,480	1,380	1,000	2.7	13.4	4.9	4.5	0.39	.001	16,900	345	99	120	72
Percentages of Bacteria removed.....													97.96	99.41	99.29	99.57

RECORD OF WORMS TILE FILTER,

For the Month of August, 1898.

Date for 24 Hours Ending 9.00 A. M.	Hours in Operation.	Quantity in Gallons.				Washing.		Iron Ore Used.		Turbidity.		Bacteria Per Cubic Centimeter.				
		Tiles.			Total Wash Water	Number of times.	Duration in Minutes.	Total Pounds.	Grains Per Gallon.	Applied Water.	Effluent.	Applied Water.	Scrubber No. 4.	Tiles.		
		D	E	F										D	E	F
1	22.8	2,370	2,040	780	320	1	7	5.4	3.6	0.42	....	48,200	570	340	190	140
2	23.7	2,750	2,130	600	0	0	0	4.2	3.0	0.70	.000	27,500	850	355	260	130
3	13.9	1,430	1,080	650	900	3	17	6.5	7.4	0.35	.001	20,200	730	630	305	90
4	17.5	1,650	1,280	790	1,640	3	24	6.2	5.9	0.15	.000	16,800	505	570	240	215
5	15.2	1,510	970	440	490	2	6	9.6	10.5	....	.000	22,300	125	185	54	42
6	9.1	880	610	360	950	3	14	5.3	10.8	0.80	.002	20,400	.....	205	29	32
7	22.2	2,480	1,770	590	0	0	0	4.8	3.9	0.26	.001	9,300	340	240	115	56
8	21.1	2,020	1,330	1,000	140	1	2	5.9	4.7	0.37	.000	11,400	180	64	30	24
9	19.4	2,050	1,350	1,030	320	1	6	7.1	5.7	0.28	.001	49,400	710	1,230	165	145
10	22.0	2,420	1,640	760	320	1	10	9.0	6.2	0.92	.000	34,400	340	230	42	50
11	16.0	1,780	1,030	530	450	2	7	4.2	5.4	0.55	.001	18,700	195	155	30	93
12	19.9	2,050	1,420	600	150	1	2	5.1	4.3	0.38	.000	9,550	190	185	48	60
13	23.4	2,300	1,610	970	290	1	2	4.8	3.4	0.31	.006	8,850	150	82	49	55
14	21.5	2,250	1,620	740	300	1	4	5.0	4.4	0.60	.001	15,500	205	250	58	38
15	23.5	2,670	1,050	1,160	150	1	2	5.4	4.3	0.24	....	10,300	225	300	74	35
16	11.5	1,050	650	480	740	2	7	3.8	8.2	0.12	.001	4,800	250	265	67	82
17	12.7	1,420	1,210	530	1,060	3	14	2.6	4.2	0.15	....	6,450	410	465	265	270
18	24.0	2,780	2,290	900	0	0	0	4.3	3.2	0.08	.000	7,300	890	900	2,240	275
19	23.6	2,680	1,220	1,920	150	1	2	2.2	1.7	0 10	.000	10,800	1,010	1,010	1,870	460
20	12.2	1,390	810	830	710	2	8	4.2	6.0	0.30	.000	27,300	790	770	425	195
21	16.1	1,240	690	400	640	2	7	4.5	8.6	1.75	.010	25,000	125	89	18	20
22	24.0	2,480	1,190	820	0	0	0	4.1	4.1	0.50	.010	22,700	225	205	19	16
23	23.0	1,880	1,070	730	320	1	4	4.5	5.4	0.31	.000	12,600	130	87	12	10
24	19.6	1,580	1,020	710	610	2	8	4.2	5.2	0.26	.000	5,600	74	83	10	8
25	23.2	1,970	1,070	730	320	1	3	3.9	4.3	0.18	.000	6,450	49	58	13	10
26	21.9	1,630	1,020	640	640	2	8	2.4	3.0	0.10	.000	1,920	110	96	51	48
27	20.6	1,670	950	640	600	2	11	3.0	4.1	0.09	.000	3,500	105	105	67	285
28	....	.....	.....	.....	.....	....	....	....	....	....	....	.....	.....	....	....	....
29	....	.....	.....	.....	.....	....	....	....	....	....	....	.....	.....	....	....	....
30	....	.....	.....	.....	.....	....	....	....	....	....	....	.....	.....	....	....	....
31	....	.....	.....	.....	.....	....	....	....	....	....	....	.....	.....	....	....	....
Totals,	523.6	52,380	34,120	20,130	12,230	39	175	132.2	....	....	....	.....	.....	....	....	....
Av'gs,	19.4	1,940	1,260	750	455	1.4	6.5	4.9	4.5	0.39	.001	16,900	365	340	325	107
Percentages of Bacteria removed.....													97.84	97.99	98.08	99.37

CHAPTER VI.

BOILER EXPERIMENTS.

Description.

It was originally intended to supply the filtered water to the boilers at the Brilliant Pumping Station. Certain obstacles were found, however, which made this impracticable. Later, the Oil Well Supply Company kindly loaned new boilers for the purpose of an experiment and three of twenty-five horse-power each, were set up in a shed, annexed to the filter building. They were operated as follows:—No. 1, with the effluent from the sand filters; No. 2, with the effluent from the mechanical filters; and No. 3, with unfiltered river water.

The boilers, which were of the locomotive type, with a steam dome near the fire box end, are such as are used generally in the oil well regions. The following are the principal dimensions, as obtained from the trade catalogue:—

Horse Power ("Oil Country" Rating)	25
Horse Power (Rating at 12 sq. ft. H. S. per H. P.)	30
Diameter	40 inches.
Length	14 feet
Height	8 "
Number of three-inch tubes	48
Length of tubes	96 inches
Heating Surface	369 square feet.
Length of Furnace	50 inches.
Width of Furnace	40 "

The boilers arrived about the middle of May and were placed in service June 5, 1898. The gas was supplied through a four-inch line, about 400 feet long, from an eight-inch main in the Pumping Station yard. The pressure was maintained at about eight ounces, by a regulator placed in the building. A three-inch pipe from the regulator passed to each gas meter, and, thence, a one and one-half-inch pipe to each boiler. Each burner consisted of a two-inch pipe, placed at right angles to the axis of the boiler and in the front part of the fire-box, a few inches above the grate. This pipe was perforated with three rows of three-eighths-inch holes, which were spaced from one-half to three-quarters of an inch apart. One row of holes was placed on top of the pipe and the other two, each one inch from this; there were 147 holes in all. A mixer, placed in front of each boiler, regulated the supply of gas and air; the latter being drawn in by a steam jet from a one-half-inch pipe. The gate was covered with a piece of sheet iron, with fire clay placed over the same, to make it tight. The gas was burned with a blue flame, as far as possible, and if any odor was noticed coming from the stacks, more steam was put on. It was endeavored to maintain a constant supply of gas at the rate of about twenty cubic feet per minute.

Water was supplied to each boiler through a three-quarter-inch pipe;

No. 1 and No. 2 were filled by injectors, the first lifting about ten feet through about fifty feet of pipe with many bends, and the second doing somewhat less work. The suction pipe for the injector to No. 2 Boiler was connected with the outlet pipe from each mechanical filter; so that the effluent from either, alone, could be used, if that from the other was for some reason objectionable. It was also possible to supply both of these boilers with the small pump, in case the injector failed to work. This happened very frequently at first. Later, however, injectors of a larger size were used with better results. Boiler No. 3 was supplied from the city main at about 140 pounds pressure.

Formation of Scale.

The boilers were drawn off occasionally, in order to observe their condition in regard to the formation of scale; sometimes by blowing off hot and sometimes by allowing the pressure to lessen and the water to cool before emptying. We found that the first method gave us a better chance to distinguish the scale and determine its characteristics; the latter allowed some of the salts to go back into solution and some of the mud to settle down to the bottom, and the scale was not as firmly baked on. For this reason, at the times upon which samples of the scale were collected and observations made, the first method of drawing off was adopted.

On August 10, 1898, all the boilers were emptied; the gas was shut off at 3.30 A. M., and the pressure gradually reduced to twenty pounds, at which time the boilers were blown off. At 10.00 A. M. the boilers were opened, hand-holes removed, and an inspection made. The best observations were made, however, some few hours later after the inside surface had been given a chance to dry. Samples of scale were collected at this time from the same place on the crown sheet of each boiler, the area of each being about sixteen square inches. Samples were also collected of the material which had oozed through the hand-holes, in Boilers No. 1 and No. 2, placed just under the flues at the smoke-box end; also one from the side of the fire-box on Boiler No. 3. The following table shows the analyses of these samples as reported by the Chemist: —

Results of Chemical Analyses of Boiler Scales, Collected, August 10, 1898.

Items.	Parts by Weight.					
Number of Sample,	1	2	3	4	5	6
Weight in Grams	19.88	40.02	29.91	....	....	....
Calcium Carbonate	33.11	17.78	32.11	3.79	7.36	1.82
Calcium Sulphate	52.03	56.98	47.46	3.77	30.23	2.38
Magnesium Carbonate	1.99	3.21	1.96	0.00	1.54	0.70
Sodium Chloride	0.00	0.00	0.78	88.32	53.82	0.00
Iron & Aluminum Oxides	2.76	5.20	1.64	0.40	2.20	85.86
Insoluble Matter	10.11	16.83	16.05	3.72	4.85	9.24
Totals	100.00	100.00	100.00	100.00	100.00	100.00

Samples Nos. 1, 2, and 3 were collected, respectively, from the crown-sheets of boilers having these numbers, and indicate the character of the formation with the different waters. As far as observation could determine, the thickness of the scale in each was about 1-32 inch, but the weights, as given, would show that the scale in Boiler No. 2 was thicker than that in either of the other two. Notes taken at the time of collection show that scale in No. 1 was "hard and tenacious." In No. 2, "hard, brittle, and cracks off easily." In No. 3, "soft and powdery." The Chemist also states that in grinding up the samples, No. 2 was found to be the hardest. Samples No. 4 and No. 5, from the hand-holes, show large amounts of sodium chloride, which evidently precipitated out of solution at this place, where the water was cooler than elsewhere. Sample No. 6 was collected from the side of the fire-box of Boiler No. 3, where a heavy granular layer was noticed on the vertical plate.

The boilers were finally blown off August 29, 1898, and by the inspection then made the scale seemed to be about the same as before. They were then returned to the owners, who made a very thorough examination and collected samples of scale. The samples were analyzed by the Chemist and the results are given below:—

Results of Chemical Analyses of Boiler Scales, Collected, September 17, 1898.

Items. Boiler and Sample Number,	Parts by Weight. 1	2	3
Calcium Carbonate	53.21	27.42	3.34
Calcium Sulphate	13.06	53.88	0.75
Magnesium Carbonate	25.33	12.58	11.06
Sodium Chloride	5.74	1.64	0.39
Iron & Aluminum Oxides	1.42	3.64	16.66
Insoluble Matter	1.24	0.84	67.80
Totals	100.00	100.00	100.00

Sample No. 1 was collected from sides at the bottom of Boiler No. 1.

Sample No. 2 was collected from the crown-sheet of Boiler No. 2.

Sample No. 3 was collected from the bottom and mud ring of Boiler No. 3.

As these samples were not taken from the same place in each boiler a comparison is somewhat more difficult than before. We have, however, the benefit of the rigid inspection made by a practical boiler man, and, by the kindness of the Oil Well Supply Company, are privileged to give abstracts of the report of their expert upon the condition of the boilers:—

Boiler No. 1:—

"The crown-sheet is covered with hard scale, the sides for about half way up are covered with a sand scale of about ⅛ inch in thickness. There is very little sediment in the mud ring, but little of the scale having dropped off. What there is, is of a decidedly sandy nature. The stay bolts and rivet heads in the bottom are thickly covered with sand. Stay bolt braces and rivet heads in top are in good condition. The tubes, as far as we can see, are in fair condition."

Boiler No. 2:—

"The crown-sheet is coated with about 1-32 inch of hard scale; the sides and bottom, also the rivet heads, are covered with a very rough coating; the rivet heads being badly corroded. There is very little sediment in the mud ring. Stay bolts in bottom are slightly coated, while those at the top are in good condition. The tubes are covered with a sandy, hard coating."

Boiler No. 3:—

"The crown-sheet is covered slightly with a soft scale, the sides are covered with a sand and mud scale, varying from ⅛ to ¼ inch in thickness, but this is loose and can easily be removed; there already being a considerable amount of same in the mud ring, which has dropped off. The stay bolts and rivet heads around the bottom are thickly covered with a loose mud sediment; the stay bolts, braces, and rivet heads above the crown-sheet are in good condition; the tubes are slightly coated."

General:—

"In our opinion Boiler No. 3 is in the best condition; for while there is considerable scale and sediment, it is soft, adheres loosely, and can easily be washed off and removed. The other boilers we would consider on a par; the only difference being that the rivets in No. 2 are badly corroded and the tubes have a thicker coating than either of the others. Considering all things, we believe this boiler to be in the worst condition of the three."

CONCLUSION.

We have, then, in conclusion, that filtration of the Allegheny River water removes the mud and insoluble matter which would, by depositing, cause the boilers to be frequently cleaned and washed out. The incrusting properties which remain, while they may not make a scale as quickly or as thick, as if greater amounts of other material were present, yet, when the deposit is formed, it is hard, of a character which gives it the name of "porcelain scale," and difficult to remove except by tools.

The results of the chemical analyses of the various samples of boiler waters will be found in Appendix No. 2, page 315. These samples were always collected from the blow-off pipes, and, when the recorded tempera-

ture is not at or near the boiling point, it means that the boiler, from which the sample was collected, was out of service at the time.

Additional reports and tables relating to various parts of the work are appended.

Respectfully submitted,

MORRIS KNOWLES,
Resident Engineer.

December 28, 1898.

APPENDICES

TO

Report of Resident Engineer,

Nos. 1-6.

EXHIBIT 5.

REPORT

UPON

Methods of Chemical Analyses and Discussion of Results,

BY

DR. WALTHER RIDDLE,

CHEMIST.

APPENDIX No. I.

APPENDIX No. 1.

MR. MORRIS KNOWLES,
Resident Engineer,
Pittsburgh Filtration Commission.

SIR:—

I beg to submit herewith my report upon the methods, and a discussion of the results, of the chemical analyses made for the Filtration Commission. The results have been reported to you from time to time during the progress of the work.

PART I.

METHODS.

The methods of chemical examination will be described in the same order as that in which the results are given in the tables, in Appendix No. 2. The solutions used will be mentioned in each case before the description of the method of analysis.

Collection of Samples and Preliminary Examination.

Half-gallon acid bottles were used in which to collect the samples. These held the amount necessary for examination, with a small margin of surplus. The collector noted upon the label the place, time of collection, temperature of water, and in the case of the river, gate chamber, and settling basin samples, after May 17, 1898, the result of the observation of the turbidity. For those samples, the turbidity of which was not determined at the time of collection, a comparison was always made with standards graded as follows:—

Turbidity.	Sediment.
1. Clear.	1. None.
2. Very Slight.	2. Very Slight.
3. Slight.	3. Slight.
4. Decided.	4. Decided.
5. Very Turbid.	5. Heavy.
6. Muddy.	6. Very Heavy.

Any odor was noted and described.

COLOR.*

Solutions.

The standard solution whose color was 5.0, was prepared as follows:—1.246 grams of potassium-platinum chloride, containing 0.5 grams of platinum and one gram of cobalt chloride (crystallized), containing 0.25

*Allen Hazen, American Chemical Journal; Vol. XIV, 1892.

gram of cobalt were dissolved in 200 c. c. (1:1) of hydrochloric acid and the solution made up to one liter. By diluting 1, 2, 3, 4, c. c., etc., up to 50 c. c., in Nessler tubes, color standards of 0.1, 0.2, 0.3, 0.4, etc., were obtained.

Method.

After a scale had been made, as described above, 50 c. c. of the sample under examination was placed in a Nessler tube. The color observed, upon looking down through the tube at a white porcelain plate, was compared with the standards until a corresponding color was found.

Fractional standards were also found to be useful.

NITROGEN AS AMMONIA.

Solutions.

1. *Nessler's Reagent:*—To prepare this solution, 35 grams of potassium iodide and 13 grams of corrosive sublimate were placed in about 600 to 700 cubic centimeters of water and heated to the boiling point. When everything was dissolved, a cold strong solution of corrosive sublimate was added, until the color of peroxide of mercury became permanent. One hundred and sixty grams of potassium hydrate were then added and the solution diluted to one liter.

2. *Standard Ammonia:*—This was made by dissolving 3.15 grams of ammonium chloride in one liter of water. This gave a strength of one milligram of ammonia to each cubic centimeter. A weaker solution was made by diluting the above solution to one-hundredth of the original strength. For very delicate work this may be diluted again; although when the one-hundredth solution was used and run in from a good burette, fractional parts were very readily determined.

3. *Caustic Permanganate:*—To prepare this, 200 grams of stick caustic potash and 8 grams of permangante of potash were dissolved in one liter of water. The solution was then boiled down, to about one-half its original bulk, in order to remove all traces of ammonia. On cooling, it was made up to one liter again with distilled water, free from ammonia.

4. *Carbonate of Soda:*—With acid waters it was necessary to add a few cubic centimeters of a saturated solution of carbonate of soda, before determining the ammonia.

Apparatus.

In our laboratory a large eight place still or condenser was used for making the ammonia distillations. The apparatus consisted of a copper tank, surrounding eight block tin worms, which at the upper end were connected with the distilling flasks. The lower ends were at such a height from the table that Nessler tubes were easily set under and withdrawn.

Method.

1. *Free Ammonia:*—Five hundred cubic centimeters of the water to be tested were placed in a one liter glass flask, and after connecting the latter with the condenser it was boiled over a Bunsen burner. The first three tubes full of distillate were set aside and nesslerized. The result obtained gives the "Nitrogen as Free Ammonia." One more portion of 50 c. c. was distilled and discarded.

2. *Albuminoid Ammonia:*—The distillation was now stopped for a time, then 50 cubic centimeters of the caustic permanganate solution were introduced into the flask and the operation continued. Three portions were again caught and nesslerized for "Albuminoid Ammonia."

Nesslerizing.

To the glass containing a portion (50 c. c.) of the distillate, two cubic centimeters of Nessler's solution were added, and the color obtained, after standing ten minutes, was compared with standards also treated with two cubic centimeters of Nessler's solution. A fresh scale of standards was generally made for each set of distillations.

NITROGEN AS NITRITES.

Solutions.

1. *Nitrite:*—A standard nitrite solution was prepared by dissolving 0.406 gram of silver nitrite in boiling water. Sodium chloride was added until no further precipitation of silver chloride occurred, and the solution was then made up to one liter.

One hundred cubic centimeters of the clear supernatant fluid were drawn off and diluted to one liter. One cubic centimeter of this solution, which was further diluted for use, is equal to one-hundredth of a milligram of nitrous acid.

2. *Color:*—The solution for obtaining the color with the nitrous acid, which may be contained in a sample of water, was made up after the method described by Leffman, which is a modification of Greiss' method.*

(a) 0.5 gram of sulphanilic acid was dissolved in 150 cubic centimeters of dilute sulphuric acid.

(b) 0.1 gram of naphthylamine was boiled with 20 cubic centimeters of water. The colorless solution was decanted and mixed with 150 cubic centimeters of dilute sulphuric acid.

The two solutions (a and b) were then mixed.

*"Examination of Water"—3d, Ed. 1895, Page 44—Henry Leffman.

Method.

Fifty cubic centimeters of the samples were placed in a Nessler tube and one cubic centimeter of the solution (2) was added. After standing twenty minutes a comparison was made with the standards.

NITROGEN AS NITRATES.

Solutions.

1. *Sodium Hydrate:*—This was prepared by dissolving 100 grams of sodium hydrate in a liter of distilled water; when the hydrate was dissolved a good sized piece of aluminum foil was dropped into the vessel. It was generally found necessary to weight the foil with a glass rod to keep it on the bottom of the containing vessel. When the aluminum was completely dissolved the solution was boiled down, until about one-half of the original bulk remained. Upon cooling, it was again made up to one liter. This solution was thus made free from nitrates.

2. *Aluminum Foil:*—This was used for generating hydrogen, by reacting with the caustic solution to reduce the nitrates to ammonia.

Method.

Two hundred cubic centimeters of the water were evaporated down to one-third of the original volume, with ten cubic centimeters of the caustic solution in a porcelain dish. On cooling, the liquid was decanted into a salt-mouth bottle of a little over 200 cubic centimeters capacity. The bottle was filled up to the 200 cubic centimeter mark and a piece of aluminum foil added. This was allowed to stand uncovered over night and the next morning 50 cubic centimeters were withdrawn and nesslerized. The amount of nitric acid was calculated from the amount of ammonia found.

During the early part of our work we distilled before nesslerizing, but this was found to be both inconvenient and unsatisfactory. It was found to be unnecessary under ordinary conditions to keep the bottles corked over night. We tried connecting a thistle tube which was filled with broken pumice soaked in dilute hydrochloric acid. By many comparisons with standards, the open bottle method proved its superiority.

CHLORINE.

Solutions.

1. *Silver Nitrate:*—This was prepared by dissolving 4.79 grams of pure silver nitrate in one liter of water. One cubic centimeter of this solution will precipitate one milligram of chlorine as silver chloride.

2. *Potassium Chromate:*—A solution of potassium chromate of a strength of about 5 grams to 100 cubic centimeters of water was used as an indicator.

Method.

One hundred cubic centimeters of water to be tested were placed in a porcelain dish, to which a few drops of the chromate solution were added. The silver nitrate solution was run in from a burette until the red color of silver chromate appeared.

RESIDUE ON EVAPORATION.

Method.

Both "Filtered Solids" and "Unfiltered Solids" were determined in all samples, which showed any considerable amount of suspended matter. The sample was thoroughly shaken in the bottle; 100 cubic centimeters were then withdrawn and evaporated to dryness in a weighed platinum dish over the water bath. After drying in this manner, the dish, with residue, was placed for ten minutes in the air bath, which was held at 104° C. to remove the last traces of water. The weight of this residue in milligrams gives the "Unfiltered Solids" in parts per 100,000. For "Filtered Solids" 100 cubic centimeters were evaporated in like manner after having been passed through a double thickness of best German filter-paper.

The difference between "Filtered" and "Unfiltered Solids" gives the result for "Suspended Matter."

For a long time, the results for "Filtered Solids," obtained by this method, were unsatisfactory. As an example:—although it was known that the hardness of the Allegheny River water was increased in passing through the sand filters, a corresponding increase of solids in the effluent, over those in the river water, was not observed. Upon investigation it was found that the best filter papers contained enough soluble matter to vitiate the results. One hundred cubic centimeters of distilled water took up, on an average, one part per 100,000, in passing through double papers. After the papers had been washed with 150 to 200 cubic centimeters of this water there was no increase. As a matter of safety, therefore, we washed the papers thoroughly with distilled water and afterwards passed about 100 cubic centimeters of the sample through, before a portion was taken for evaporation, and after this we had no trouble.

LOSS ON IGNITION.

Method.

After the determination of "Filtered Solids" the dish was heated over a Bunsen burner to a faint red heat and the loss in weight noted in milligrams.

HARDNESS.

Solution.

Standard Soap:—A solution of castile soap in 35% alcohol was balanced against a standard solution of calcium carbonate, containing one milligram of carbonate of lime to the cubic centimeter. As 100 cubic centimeters of distilled water will produce a lather only after about one cubic centimeter of soap solution is added, a correction had to be made for this. The soap solution was standardized, so that 100 cubic centimeters of solution containing 10 milligrams of carbonate of lime required 11 cubic centimeters of the soap solution. Then in each case the number of cubic centimeters of soap solution minus one gives the "Hardness," expressed in parts per 100,000.

Method.

One hundred cubic centimeters of the sample were placed in a glass stoppered bottle, of about 250 cubic centimeters capacity, and soap solution was run in slowly with frequent shakings of the bottle, until a persistent lather was formed.

There are many objections to the soap method of determining "Hardness." It is perhaps not to be commended for accuracy, but where experiments are undertaken with a view to ascertaining the suitability of a water supply for household purposes, the effect upon the soap consumption is a matter of great moment. This is especially the case in a city like Pittsburgh.

ALKALINITY.

Solution.

Sulphuric Acid:—A fiftieth normal solution of this acid was used. One cubic centimeter of this solution will neutralize one milligram of calcium carbonate, and the results are therefore reported in parts per 100,000 of this carbonate.

Method.

One hundred cubic centimeters of the sample were placed in a 200 c. c. porcelain dish, to which a drop of methyl orange indicator was added. The $\frac{N}{50}$ acid was then run in drop by drop from a burette, until the yellow color of the methyl orange just began to turn pink. The great advantage of the methyl orange is that the determination may be carried out in the cold.

SULPHURIC ACID.

Solutions.

Barium Chloride :—A solution containing 100 grams of this salt to the liter is used.

Method.

Two hundred cubic centimeters of the sample, which must have been filtered if not already clear, were used for the determination. Two cubic centimeters of the barium chloride solution and a few drops of hydrochloric acid were added and the solution evaporated in a beaker on the hot plate, to a small bulk, or until the barium sulphate was completely precipitated. The precipitate was filtered, washed, ignited, and weighed as barium sulphate and the sulphuric acid calculated from the result.

IRON.

Solutions.

1. *Standard Iron:*—This was prepared by dissolving 0.7 gram of ferrous ammonium sulphate in water, which was acidified with sulphuric acid and then oxidized with permanganate of potash and finally diluted to one liter. The strength was therefore one-tenth milligram to one cubic centimeter. Another standard was made by diluting the above named solution ten times, which gave one one-hundredth milligram to one cubic centimeter.

2. *Sulphuric Acid:*—A 30% solution of this was prepared.

3. *Thiocyanate :*—A solution containing 50 grams to the liter of potassium sulphocyanate was used.

Method.

One hundred cubic centimeters of the sample were first evaporated to dryness and then taken up with dilute hydrochloric acid, after which a little permanganate was added. The excess of hydrochloric acid was boiled off and 5 cubic centimeters of sulphuric acid (30% solution) with 15 cubic centimeters of thiocyanate were added. This solution was then diluted to the original volume (100 c. c.). The depth of color of the sample, after the above treatment, was compared with standards treated in the same way, until a good match was found.

ALUMINA.

Solutions.

1. *Alum:*—A standard solution was made up of such strength, that each cubic centimeter contained one milligram of oxide of aluminum. Portions of this solution were readily diluted, so that each cubic centimeter contained one one-hundredth milligram of alumina.

2. *Logwood:*—This was prepared by making successive infusions of logwood chips. The first four were decanted and discarded and the fifth was saved for use. It was generally found better to prepare a fresh solution for each set of determinations.

Method.

Five hundred cubic centimeters of the water were evaporated to small bulk and placed in a Nessler tube. If necessary this was diluted to the mark, and then one cubic centimeter of logwood solution was added. The color obtained was compared with standards similarly treated. This method was found to be somewhat erratic. The color was often brought out by the addition of a few drops of acetic acid.

DISSOLVED OXYGEN.

Solutions.

1. *Manganous Sulphate:*—This was prepared by dissolving about 30 grams of the salt in the least quantity of water.

2. *Sodium Hydrate:*—A saturated solution containing about 10 grams of potassium iodide to 100 cubic centimeters was used.

3. *Sodium Thiosulphate:*—For titrating the liberated iodide a one-hundredth normal solution was used.

Method.

The sample was collected in a bottle of about 250 c. c. capacity, which was carefully calibrated, and the temperature of the water at time of taking the sample was noted. With a small pipette one cubic centimeter of the potassium iodide solution was added; then one cubic centimeter of the manganous sulphate solution was run in carefully with a pipette and the bottle was shaken up. The liberated iodine was titrated with the thiosulphate solution. Results were calculated to milligrams of oxygen per liter and were reported in percentages of the amount held by distilled water, saturated with air at the same temperature. A table giving the quantity of dissolved oxygen in water saturated with air for the temperatures from 32°F. to 36°F. was used.

PART II.

Discussion.

In the tables, found in Appendix No. 2, the results are grouped according to the locality at which samples were collected.

In regard to the general character of the Allegheny River and Monongahela River waters the following may be stated:—The appearance of the waters changes very quickly after rains, as is shown by the figures in the column headed "Turbidity." The dissolved solids vary according to the height of the rivers. After heavy rains the amount of solids in solution is small. The color of the river water has generally been due to suspended matter, though, occasionally, dissolved color has been found which has not been removed by filtration except with the use of coagulant.

Chlorine is always present, the Allegheny containing more than the Monongahela. At some points on the Allegheny, Montrose Pumping Station in particular, the chlorine figures were frequently very large. This is probably not due to sewage contamination, as the free ammonia is not correspondingly abundant, but to subterranean waters. On drilling the well at Brilliant, salt water was found at a depth of 141 feet. The Allegheny and its tributaries drain the oil country where, in drilling for oil, salt water has often been found.

The Monongahela River water contains large proportionate amounts of sulphuric acid, due to the mine waters discharged into it by the Youghiogheny River, Turtle Creek, and other streams.

The water at Twenty-ninth Street, where we obtained our samples never gave an acid reaction with methyl orange. The fact that the Monongahela River is slack water has a great bearing upon its chemical character. During long dry spells, the flow of water from the mines being practically constant, the water in the pools formed by the dams becomes very acid. During the time in which the Filtration Commission has been making observations, we have had no very protracted dry spells, and we have not been able to test the Monongahela water when in this peculiar condition.

As a rule, the Allegheny River is less heavily charged with organic matter than the Monongahela. At Brilliant, on the Allegheny, we have found a variation of from 0.0042 to 0.0360 parts per 100,000 of nitrogen, as albuminoid ammonia. The nitrogen as nitrates shows a variation of from 0.0018 to 0.2100 parts per 100,000. Nitrogen very seldom occurs as nitrites showing that oxidation is very complete. The percentage of saturation with oxygen of the samples of water collected from the gate chamber of the sand filters which corresponds to the river water, has always been high.

Very respectfully,

WALTHER RIDDLE,

Chemist.

November 30, 1898.

DESCRIPTION

OF

Sources of Samples

AND

Results of Chemical Analyses,

ALSO

Number of Bacteria per Cubic Centimeter.

APPENDIX No. 2.

APPENDIX No. 2.

In this appendix a short description is given of the sources from which samples were collected, followed in each case by a table of the results of the chemical analyses. The last column of the tables shows the number of bacteria per cubic centimeter, counted in the corresponding bacterial sample, collected at the same time. In the case of the samples collected from the gate chamber, settling basin, and effluents from filters, the number of bacteria given is the average for the twenty-four hours ending 9.00 A. M., of the date following the calendar date given in the second column. The statements about the sources of the samples, not collected at the experimental filter plant, were obtained from the officials in charge of the various works.

In addition to those samples relating directly to the filter experiments, others were collected occasionally, of the water supplies of Pittsburgh, Allegheny, and of some of the neighboring places. It was desired especially to learn about the character of the water obtained from the various cribs in the Allegheny River. A study of the results given in the several tables will show to what extent these devices changed the character of the river water, and it may be readily seen that, in general, the effluents from the cribs were clear and nearly free from suspended matter, except after an occasional very muddy period of the river; that the number of bacteria in the same was usually less than in the river, and that the hardness of the water from the cribs was materially greater than that of the samples of river water. It should be noted, in exception to the above, that the effluents from the cribs at Montrose and Millvale differed but very little, in regard to the items mentioned, from the river water.

ALLEGHENY RIVER AT BRILLIANT.

Samples of the "Allegheny River at Brilliant" were collected about once a week, from the beginning of the work until March 1, 1898; for the next three months samples were collected twice a week, and after June 1, 1898, samples were again collected once a week, until the close of the experiments. Additional samples were occasionally collected, for the special determination of the "Suspended Matter," and the turbidities were observed by the stick scale method at the same time. The results of the analyses of these special samples are given last.

The water supply of Wards 1-23, inclusive, of Pittsburgh, is obtained from the river at Brilliant Pumping Station. The intakes to the pump wells are three 36-inch pipes and one 48-inch pipe; the former being 180 feet long and the latter 230 feet. The outer ends of these pipes are protected by timber cribs, which are covered with "T" rails, spaced four inches apart, and riprapped with stone.

The samples were collected, sometimes from a boat in the stream over the intake, but more often from the current passing by a raft of logs, moored to the bank, about 800 feet above the pumping station.

Allegheny River at Brilliant.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897															
5	June 8	.....	...	.0140	.0013	...	...	3.60	21.6	...	7.0	9.10	...	1.65	...	.....
11	" 15	Dec'd	...	.0140	.0000	...	...	1.80	11.2	...	5.6	9.60	...	1.09	..	.....
22	" 23	.....	...	.0130	.0000	.0000	.0170	1.60	11.2	...	3.6	7.30	...	1.82	...	.....
27	" 28	.....	...	.0140	.0010	.0000	.0180	2.60	12.4	...	6.4	4.60	...	1.05	...	.....
	Av'gs,	.....	...	.0137	.0006	.0000	.0175	2.40	14.1	...	5.6	7.65	...	1.40	...	.....
33	July 7	Dec'd	...	.0220	.0050	.0000	.0092	3.80	18.4	2.0	6.4	6.30	...	1.65	...	15,645
41	" 13	"	...	.0136	.0014	.0001	.0018	4.75	19.6	0.8	7.4	6.27	8.00	0.93	.003	3,160
51	" 19	Slight	...	.0222	.0012	.0001	.0075	2.78	15.7	0.0	6.0	6.20	6.50	1.41	.070	.....
59	" 23	Mud'y	...	.0650	.0060	.0001	.0240	1.20	53.9	41.8	8.5	4 60	3.75	Tr.	.480	.....
	Av'gs,	.....	...	.0307	.0034	.0001	.0106	3.13	26.9	11.1	7.1	5.84	6.08	1.33	.184	9,402
150	Aug. 24	Slight	...	.0210	.0023	.0000	.1050	2.03	9.0	1.0	5.0	5.41	4.05	0.86	.007	.....
194	Sept. 2	Dec'd	.45	.0160	.0035	.0000	.0825	2.27	10.4	...	3.8	5.54	4.55	1.30	.044	.....
272	" 23	Slight	.25	.0116	.0010	.0000	.0487	3.31	14.0	...	5.6	5.55	5.49	2.82	.060	.....
303	" 30	V.sl'gt	.40	.0122	.0012	.0000	.0638	2.43	14.8	...	5.2	4.01	3.85	2.33	.086	.....
	Av'gs,	.....	.37	.0133	.0019	.0000	.0650	2.70	13.1	...	4.9	5.03	4.63	1.82	.063	.....
346	Oct. 11	V.sl'gt	.30	.0146	.0016	.0000	.0675	3.55	17.6	...	7.2	5.73	5.20	1.75	.062	14,000
373	" 18	V. "	.20	0108	.0018	.0000	.0750	3.45	18.4	...	6.8	5.52	5.01	2.51	.032	75,000
405	" 25	Slight	.20	.0105	.0018	.0000	.0225	4.44	17.0	...	5.0	5.22	5.06	2 68	.044	59,500
	Av'gs,	.....	.23	.0120	.0017	.0000	.0550	3.81	17.7	...	6.3	5.49	5.09	2.31	.046	49,500

Allegheny River at Brilliant.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
432	Nov. 1	V. sl'gt.	.20	.0110	.0024	.0000	.0225	4.16	18.8	0.2	6.4	5.42	5.14	2.88	.052	155,200
464	" 8	Slight	.20	.0120	.0020	.0000	.0525	4.41	21.6	0.2	7.6	4.90	4.65	3.51	.070	10,900
480	" 11	"	.25	.0168	.0024	.0000	.0300	3.36	23.6	0.4	9.2	3.20	3.09	1.00	.068	.....
490	" 15	Dec'd	.40	0224	.0024	.0000	.0900	3.67	21.6	2.4	6.0	4.18	3.98	1.89	.144	6,750
519	" 23	Slight	.40	0120	.0012	.0000	.0900	1.78	12.4	0.4	5.6	2.83	2.09	1.16	066	.....
539	" 29	Dec'd	.30	.0168	.0008	.0000	.1350	1.51	20.0	8.4	6.8	2.80	2.13	1.06	.170	36,400
	Av'gs,	.....	.29	.0152	.0019	.0000	.0700	3.15	19.7	2.0	6.9	3.89	3.51	2.47	.095	52,312
556	Dec. 6	Slight	.30	.0118	.0012	0000	.1650	1.70	44.0	31.6	6.8	1.68	1.31	2.02	.200	.....
572	" 13	"	.30	.0110	.0020	0000	.0450	1.80	13.6	0.2	4.4	2.96	2.53	1.37	.115	8,900
608	" 28	V. sl'gt.	.30	.0104	.0014	.0000	.1125	2.82	13.6	0.2	5.2	2.09	1.32	1.99	.054	1,300
	Av'gs,	.....	.30	.0111	.0015	.0000	.1075	2.11	23.7	10.7	5.5	2.24	1.72	1.79	.123	5,100
	1898.															
624	Jan. 3	V. sl'gt.	.30	.0056	.0024	.0000	.0900	2.30	13.2	0.0	4.0	3.14	2.28	2.44	.066	1,100
637	" 10	Slight	.30	.0070	.0010	.0000	.0750	1.91	21.6	8.8	7.2	2.17	1.86	1.47	.184	12,800
663	" 17	"	.30	.0084	.0012	.0000	.1200	1.19	13.6	3.2	4.8	1.42	1.20	1.20	.050	45,200
681	" 24	Dec'd	.30	.0104	.0012	0000	.0600	0.90	20.4	12.0	7.6	1.64	1.02	0.92	.200	20,600
697	" 31	Slight	.20	.0058	.0020	.0000	.0975	1.33	7.6	0.0	2.4	2.10	1.04	1.13	.062	2,700
	Av'gs,	.....	.28	.0074	.0016	.0000	.0885	1.53	15.3	4.8	5.2	2.09	1.48	1.43	.112	16,480
717	Feb. 7	V. sl'gt.	.20	.0052	.0016	0000	.1575	1.69	14.8	0.0	7.2	2.63	1.99	1.75	.056	1,500
737	" 14	Slight	.20	.0064	.0016	.0000	.2100	1.31	13.6	4.2	4.4	2.42	1.40	0.79	.014	20,500
756	" 21	"	.15	.0220	.0016	.0000	...	1.30	12.4	2.0	4.4	2.87	1.84	1.16	.150	13,000
769	" 25	"	.25	.0096	.0036	0000	...	1.54	10.0	0.4	3.2	2.84	1.92	1.18	.046	7,400
774	" 28	"	.25	.0064	.0016	.0000	.0600	1.44	8.6	0.2	3.2	2.18	1.52	1.30	.030	.. ...
	Av'gs,	.....	.21	.0099	.0020	.0000	.1425	1.46	11.9	1.4	4.5	2.59	1.73	1.24	.059	10,600

Allegheny River at Brilliant.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
788	Mar. 4	V.sl'gt.	.25	.0042	.0018	.0000	.0675	1.98	10.2	0.2	2.4	3.24	2.21	1.34	.045	5,650
792	" 7	Slight	.25	.0042	.0022	.0000	.0525	1.45	9.2	0.4	3.2	3.10	2.30	1.75	.025	4,300
804	" 11	"	.25	.0042	.0014	.0000	.0450	1.49	9.8	0.2	3.6	3.16	2.31	1.58	.035	4,500
812	" 14	"	.22	.0062	.0012	.0000	.0375	1.60	8.8	0.4	2.8	2.78	1.94	1.20	.024	12,000
826	" 17	"	.22	.0062	.0012	.0000	.0525	1.18	8.2	0.2	3.2	2 94	1.62	0.61	.035	8,150
827	" 21	Mud'y	20	.0140	.0014	.0000	.0525	1.09	34.4	21.6	4.0	1.88	1.38	0.65	090	.....
840	" 25	V.t'd	.25	.0096	.0018	.0000	.0525	0.61	22.0	11.6	2.8	1.84	1.05	1.15	.046	13,500
847	" 29	Slight	.27	.0120	.0014	.0000	.0300	0.93	9.2	0.2	3.4	2.84	1.21	1.13	.018	5,650
	Av'gs,	.....	.24	.0076	.0015	.0000	.0487	1.29	14.0	4.3	3.2	2.72	1.75	1.18	.040	7,679
861	Apr. 1	Dec'd	.25	.0098	.0012	.0000	.0375	0.91	9.6	0.8	2.8	2.08	1.30	0.79	.052	4,800
868	" 4	Slight	.22	.0054	.0020	.0000	.0525	1.17	8.5	0.1	2 0	2.28	1.37	1.14	.033	1,800
881	" 8	V.sl'gt.	20	.0062	.0012	.0000	.0450	1.40	10.8	0.2	4.0	2.06	1.70	0.61	.048	1,600
887	" 11	Slight	.22	.0072	.0020	.0000	.0600	1.30	8.0	0.0	2.0	2.30	1.90	1.44	.040	1,350
899	" 15	"	.20	.0042	.0020	.0000	.0525	1.88	11.2	0.0	6.0	2.44	2.20	1.50	.050	3,350
906	" 18	"	.20	.0124	.0020	.0000	.0450	1.55	9.4	0.2	2.2	1.88	1.71	1.47	.030	1,300
919	" 22	V.sl'gt.	.17	.0068	.0016	.0000	.0300	1.66	10.6	0.2	4.8	2 40	2.00	1.27	.060	950
924	" 25	Slight	.25	.0084	.0032	.0000	.0525	1.32	8.6	0.2	3.6	3.00	2.46	1.07	.030	9,250
939	" 29	"	.25	.0088	.0014	.0000	.0375	1.09	8.3	0.3	3.2	2.18	1.85	0 44	.030	6,850
	Av'gs,	.....	.22	.0077	.0018	.0000	.0458	1.36	9.4	0.2	3.4	2.29	1.83	1.08	.041	3,472
944	May 2	V.sl'gt.	.25	.0108	.0016	.0000	.0300	1.40	8.2	0.2	3.6	2.38	2.10	0.34	.020	2,500
962	" 5	V. "	.25	.0078	.0018	.0000	.0150	1.35	8.8	0.0	2.8	2.62	2.10	0.52	.030	1,800
968	" 9	Dec'd	.30	0200	.0020	.0000	.0225	1.18	12.0	4.0	3.2	2.08	1.70	1.27	.096	19,300
986	" 13	V.sl'gt.	.25	.0122	0014	.0000	.0150	1.58	8.6	0.2	2.8	2.80	2.15	1.07	.003	2,200
991	" 15	Dec'd	.25	.0110	.0012	.0000	.0075	2.92	11.6	1.4	3.8	3.70	2.72	0.96	.030	.....
1003	" 16	Mud'y	40	.0300	.0024	.0000	.0075	2.62	45.9	34.5	3.7	2.80	2.82	1.35	050	17,800
1004	" 17	"	40	.0360	.0022	.0000	.0075	1 60	70.4	60.6	3.4	3.38	1.89	1.86	032	63,700
1007	" 18	"	.35	.0174	.0010	.0000	.0075	1.40	21.7	13.3	3.3	2.80	1.77	1 10	.036	34,100
1021	" 23	Dec'd	.30	.0130	.0004	.0000	0300	1.00	12.1	4.3	4.4	2.80	1.81	0.55	.022	7,000
1042	" 31	Slight	.30	.0060	.0008	.0000	.0375	1.53	7.4	0.3	3.6	2.60	2.20	0.96	.014	1,700
	Av'gs,	.....	.30	.0164	.0015	.0000	.0180	1.66	20.7	11.9	3.5	2.80	2.13	1.00	.033	16,700

Allegheny River at Brilliant.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
1065	June 6	V. sl'gt.	.22	.0062	.0018	.0000	.0375	2.78	8.2	0.1	3.6	3.20	2.92	0.88	.006	1,850
1084	" 13	Slight	.30	.0100	.0024	.0000	.0300	2.52	12.4	0.6	4.4	3.48	3.30	1.54	.006	4,650
1109	" 20	0.60	.30	.0110	.0010	.0000	.0150	1.79	37.8	28.0	4.8	4.10	3.18	0.96	.020	18,600
1135	" 27	0.09	.20	.0070	.0024	.0000	.0375	2.60	18.0	7.4	4.5	3.28	3.00	0.79	.010	4,500
	Av'gs,	0.34	.25	.0085	.0019	.0000	.0300	2.42	19.1	9.0	4.3	3.51	3.10	1.04	.010	7,400
1161	July 5	0.08	.27	.0132	.0020	.0000	.0825	1 60	10.4	2.0	3.8	3.44	2.78	0.17	.024	1,650
1186	" 11	0.02	.27	.0108	.0042	.0000	.0900	2.38	12.0	2.6	3.6	3.88	3.30	1.30	.018	9,700
1207	" 18	0.08	.27	.0080	.0018	.0000	.0525	3.05	14.4	0.2	4.6	5.34	3 96	1.79	.028	19,900
1236	" 25	0.11	.27	.0080	.0028	.0000	.0525	2.86	15.8	0.8	5.2	5.48	3.62	2.93	.010	13,600
	Av'gs,	0.07	.27	.0100	.0027	.0000	.0694	2.47	13.1	1.4	4.3	4.53	3.41	1.55	.020	11,200
1254	Aug. 1	0.70	.25	.0120	.0030	.0000	.0525	4.10	36.0	20.8	5.0	5.82	4.50	1.61	.030	49,700
1284	" 8	0.21	.27	.0106	.0024	.0000	.0375	2.58	18.2	6.0	4.0	3.84	3.32	0.71	.016	5,400
1314	" 15	0.11	.30	.0105	.0022	.0000	.0525	2.18	13.8	4.9	3.7	3.70	2.82	1.20	.026	5,500
1344	" 22	0.20	.35	.0106	.0022	.0000	.0225	1.56	18.6	10.8	4.0	2.70	2.12	0.82	.014	12,600
1376	" 29	0.07	.40	.0078	0020	.0000	.0525	1.68	11.0	1.6	4.5	3.90	3.00	0.30	.012	.....
	Av'gs,	0.26	.31	.0103	.0024	.0000	.0435	2.42	19.5	8.8	4.2	3.99	3.15	0.93	.020	18,300

Allegheny River at Brilliant. (Special.)

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898															
1015	May 18	0.63	...	...	...	...	...	...	23.1	14.4	3.5	...	2 04	...	...	34,100
1013	" 19	0.13	...	...	...	...	...	...	14.6	6.1	3.9	...	2.12	...	...	9,850
1017	" 19	0.17	...	...	...	...	...	...	14.3	5.7	3.6	...	1.81	...	...	9,850
1014	" 20	0.16	...	...	...	...	...	...	12.6	2.0	5.4	...	1.96	...	...	9,000
1018	" 21	0.45	...	...	...	...	...	...	26.4	17.4	4.4	...	2.26	...	...	.....
1020	" 22	V. t'd	.40	...	...	.0000	.0375	1.10	20.5	11.9	4.2	2.60	1.54	...	.026	7,000
1030	" 24	"	.30	...	...	.0000	...	0.94	24.9	17.5	3.4	2.60	2.00	...	.024	.....
1034	" 24	"	.35	...	...	.0000	...	1.05	20.6	13.2	3.6	2.70	1.79	...	.026	16,600
1035	" 24	"	.30	...	...	.0000	...	0.72	14.3	6.7	3.6	3.00	2.63	...	.035	12,200
1038	" 25	.....	.35	...	...	.0000	...	1.03	18.3	10.7	3 4	2.42	1.81	...	.032	.....
1039	" 26	Slight	.30	...	...	.0000	...	1.18	10.7	3.3	3.8	...	1.90	...	.025	6,000
1040	" 27	"	.30	...	...	.0000	...	1.12	10.3	3.7	3.2	2.10	1.92	...	.014	3,350
	Av'gs,	.....	.33	...	...	.0000	...	1.02	17.5	9.4	3.8	2 57	1.98	...	.026	12,000
1100	June 14	Dec'd	.30	...	...	...	...	2.72	29.6	16.6	5.4	3.70	3.30	1.58	.024	4,650
1105	" 15	0.90	30	...	...	...	...	1.70	32 2	20.9	4.6	2.48	2.10	...	.040	.....
1106	" 16	0.31	.27	...	...	...	...	1.58	19 0	7.7	5.2	2.66	2.50	...	.036	.....
1107	" 17	0.17	.27	...	...	...	...	1.60	14.8	5.0	4.4	2 90	2.70	1.41	.016	.....
1119	" 18	Slight	.30	...	...	.0000	...	2.00	17.5	7.3	3.9	3.60	3.01	1.13	.012	.....
1120	" 19	0.60	.35	...	...	.0000	...	3.90	34.8	22.2	4.5	4.10	3.12	1.23	.025	.....
1147	" 20	0.90	.30	...	...	...	...	1.94	50.8	40.2	3.4	3.36	3.24	0.96	.028	18,600
1127	" 21	0.70	.27	...	...	.0000	...	1.82	35.2	25.0	4.0	2.95	2.50	1.00	.036	.....
1146	" 23	0.16	.40	...	...	...	...	2.08	15.2	5.0	3.4	3.18	3.01	1.13	.018	.....
1156	" 30	0.12	.20	...	...	...	...	2.10	17.0	6.8	4.6	3.68	3.53	0.85	.018	4,300
	Av'gs,	0.48	.30	...	...	.0000	...	2.14	26.6	15.7	4.3	3.26	2.90	1.16	.025	9,200
1158	July 1	0.24	.30	...	...	.0000	...	1.10	12.8	4.4	3.6	3.20	3.12	0.68	.024	.....
1159	" 2	0.13	.30	...	...	.0000	...	1.40	11.2	3.1	3.8	3.05	3.02	0.32	.030	.....
1168	" 3	0.11	.30	...	...	...	...	1.50	13.2	4.7	4.0	3.68	2.72	0.41	.018	.....
1205	" 16	0.55	.30	...	...	...	...	8.84	31.9	3.1	8.2	6.60	3.40	1.82	.038	.....
	Av'gs,	0.26	.30	...	...	.0000	...	3.21	17.3	3.8	4 9	4.13	3.06	0.81	.027	.....

Allegheny River at Brilliant. (Special.)

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898															
1280	Aug. 1	.....	.22	...	...	...	...	5.84	37.5	20.0	5.0	6.30	4.65	1.65	.010	49,700
1281	" 3	0.18	.20	...	...	...	...	3.92	23.0	7.8	4.2	6.48	4 72	2.06	.011	.....
1282	" 4	0.20	.22	...	...	...	...	4.12	21.0	4.4	4.8	6.60	4.20	2.31	.018	.....
1283	" 5	0.80	.27	...	...	...	...	5.50	31.4	14.6	4.8	6.20	4.12	2.20	.020	.....
1301	" 6	0.24	.20	...	...	.0000	...	3.52	20.8	6.0	4.2	4.32	4.00	2.06	.020	.....
1302	" 8	0.85	.25	...	...	.0000	...	4.72	46.4	29.4	4.6	4.18	3.72	1.54	.016	5,400
1303	" 9	0.88	.27	...	...	.0000	...	3.20	33.2	18 6	4.4	4.80	3.20	1.72	.026	.....
1309	" 9	0.80	.30	...	...	.0000	...	2.62	45.1	32.3	3.4	3.98	3.00	1.50	014	.....
1310	" 10	0.65	.30	...	...	.0000	...	2.30	35.2	23.0	3 2	4.00	2.27	1.53	.016	.....
1312	" 10	Dec'd	.30	...	...	.0000	...	2.68	37.1	23.7	3.8	4.00	3.02	1.47	.016	.....
1311	" 11	0.42	.30	...	...	.0000	...	2.24	21.8	10.2	3.3	3.40	2.16	1.72	.012	.....
1340	" 16	0.14	.25	...	...	.0000	...	2.50	15.4	3.7	4.4	4.68	3.10	1.54	.014	5,500
1341	" 18	0.14	.25	...	...	.0000	...	2.80	15.6	5.1	4.3	4.90	3.50	1.79	.012	.....
1342	" 19	0.80	.30	...	...	.0000	...	2.78	78.6	69.2	4.0	4.88	3.38	1.41	.012	.....
1343	" 20	1.20	.27	...	...	.0000	...	1.70	80.6	72.6	4.0	3.18	1.80	1.62	.008	.....
1359	" 21	0.45	.32	...	...	.0000	...	1.44	24.4	15.7	3.6	2.74	2.00	1.03	.014	.....
1362	" 23	0.24	.40	...	...	.0000	...	1.40	21.2	11.8	4.2	2.88	1.90	0.89	.018	12,600
1373	" 24	0.15	.40	...	...	.0000	...	1.52	12.4	3.4	3.1	3.50	2.60	0.96	.014	.....
1374	" 25	0.10	.40	...	...	...	...	2.10	11.0	2.4	2.8	3.22	2.68	0.65	.014	.....
1375	" 27	0.15	.35	...	...	.0000	...	1.80	12.1	3.4	4.0	3.12	2.10	0.41	.010	.....
	Av'gs,	0.47	.29	...	...	.0000	...	2.93	31.2	18.9	4.0	4.37	3.11	1.50	.015	18,300

Mineral Analysis.

Sample Collected September 19, 1898.

(PARTS PER 100,000.)

Total Solids	12.70
Loss on Ignition	4.30
Calcium Oxide, (CaO)	2.04
Magnesium Oxide, (MgO)	0.49
Sulphuric Acid, (SO_3)	1.61
Chlorine, (Cl)	2.29
Silica, (SiO_2)	0.10
Iron Oxide, (Fe_2O_3)	0.01

PITTSBURGH CITY TAP.

Samples of "Tap Water" in the city of Pittsburgh were collected about once a week during the months of June to November, inclusive, 1897, and then occasionally until March 1, 1898.

All of the water pumped from Brilliant, first passes into the Highland Reservoir, of about 117,000,000 gallons capacity, and then is distributed over the city.

At first these samples were collected in the laboratory of Coster & Riddle, and later, after October, 1897, in a blacksmith-shop in Cherry Alley, near the Public Safety Building. The second sample, dated September 22, 1897, and the one dated September 27, 1897, were also collected at the latter place.

Pittsburgh City Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897															
6	June 9	.....	...	.0085	.0001	...	...	2.70	13.2	...	6.2	8.50	...	1.70	...	.....
14	" 16	.....	...	.0150	.0000	...	...	2.00	16.0	...	8.0	11.80	...	1.20	...	.....
23	" 24	.....	...	.0110	.0030	.0000	.0000	2.00	9.2	...	4.4	7.20	...	1.41	.000	.....
28	" 29	.....	...	.0130	.0000	.0000	.0180	2.20	13.2	...	5.6	5.20	...	1.51	.000	.....
	Av'gs,	.....	...	.0119	.0008	.0000	.0090	2.22	12.9	...	6.0	8.17	...	1.45	.000	.....
34	July 7	.....	...	.0200	.0020	.0000	.0090	6.00	18.0	3.2	6.8	6.00	...	1.54	...	...
42	" 13	Dec'd	...	.0190	.0004	.0002	.0052	2.62	16.4	0.6	7.2	5.61	8.50	1.28	.006	250
52	" 19	"	...	.0206	.0016	.0001	.0150	3.67	18.6	3.1	6.2	6.45	7.50	1.58	.150	...
	Av'gs,	.....	...	.0199	.0013	.0001	.0097	4.10	17.7	2.3	6.7	6.02	8.00	1.46	.078	250
84	Aug. 4	Slight	...	.0205	.0028	.0000	.0963	1.10	10.3	1.2	4.3	3.87	4.90	0.89	.135	106
107	" 12	"	...	.0144	.0012	.0000	.0814	2 20	14 2	4.6	5.2	6.05	6.25	1.30	.150	...
133	" 20	"	...	.0182	.0017	0000	.0525	1.25	12.8	4.6	5.2	5.74	4.35	0.62	.240	...
161	" 26	Dec'd	...	.0181	.0018	.0000	.0600	1.72	9.6	...	3.6	5.72	3.79	1.06	.050	242
	Av'gs,	.....	...	.0178	.0019	.0000	.0725	1.57	11.7	2.6	4.6	5.34	4.82	0.97	.144	174

Pittsburgh City Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
220	Sept. 9	V. sl'gt.	.45	.0136	.0016	.0000	.0450	2.07	14.8	...	6.4	5 74	4.84	1.10	.030	...
261	" 22	Slight	.25	.0142	.0014	.0000	.0412	2.84	15.2	...	6.4	7.03	5.67	1 85	.054	162
269	" 22	"	.20	.0126	.0018	.0000	.0450	2.73	14 4	...	4.4	5.45	5.31	1.78	.030	162
279	" 27	"	.40	.0116	.0008	.0000	.0675	3.12	14.8	...	5.2	4.76	4.60	2.92	034	...
308	" 30	"	.35	.0138	.0015	.0000	.0562	2.56	15.6	...	6.0	4.50	4.30	2.47	.058	596
	Av'gs,	.....	.33	.0132	.0014	.0000	.0510	2.66	15.0	...	5.7	5.50	4.94	2.02	041	307
313	Oct. 4	V. sl'gt.	.30	.0140	.0008	.0000	.0970	2.91	15 8	...	5.6	5.10	4.85	2.85	.056	812
339	" 11	V. "	.30	0120	.0018	.0000	.1050	3.06	16.0	...	6.8	...	4.65	4.30	.038	3,220
370	" 18	V. "	.20	.0138	.0020	.0000	.0750	3.25	16.4	...	6.4	4.98	4.65	2.29	.015	3,848
400	" 25	V. "	.20	0220	.0030	.0000	.0375	3.32	16.4	...	5.6	5.24	5.03	2.61	.036	20,898
	Av'gs,	.....	.25	.0154	.0019	.0000	.0786	3.13	16.1	...	6.1	5.11	4.79	3.01	.036	7,194
429	Nov. 1	V. slg't.	.20	.0060	0040	.0000	.0600	3.87	17.6	0.2	8.8	5.01	4.77	3.02	.040	31,360
461	" 8	Slight	.25	.0120	.0016	.0000	.0525	3 90	24 4	0.1	8.0	5 06	4.79	3.40	.052	12,950
509	" 22	"	.30	.0124	.0006	.0000	.0675	2.16	14.0	0.2	5 6	3.10	2.60	1.19	.062	8,350
	Av'ge,	.....	.25	.0101	.0021	.0000	.0600	3.31	18.7	0.2	7.5	4.39	4.05	2.54	.051	17,633
590	Dec. 20	Slight	.30	.0074	.0014	.0000	.0600	1.64	15,2	5.2	6.0	2.13	1.86	1.27	.132	.....
	1898.															
660	Jan. 17	Slight	.30	.0096	.0018	.0000	.0975	1.12	14.0	2.8	5.2	1.40	1.24	1.28	.130	14,000
809	Mar. 14	Slight	.25	.0056	.0018	.0000	.0450	1.34	10.6	0.2	4.0	3.15	2.31	1.37	.020	4,300

GATE CHAMBER.

Samples from the "Gate Chamber" were collected, after the sand filters were placed in operation, twice a week until December, 1897, and, since then, once a week until the close of the experiments. Four additional samples were obtained for the special determination of "Suspended Matter."

These samples were collected a short distance below the surface of the water in the "Gate Chamber," where the inlet pipe entered to supply water to the Sand Filter Plant.

Gate Chamber.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
64	July 26	0.50	...	.0250	.0023	.0000	.1850	1.09	12.4	2.6	3 9	4.88	5.14	0.98	.140	1,300
72	" 29	0.52	...	.0270	.0018	.0002	.1112	1.15	17.7	9.5	3.8	3.90	4.29	1.17	.230	3,250
	Av'gs,	0.51	...	.0260	.0020	.0001	.1481	1.12	15.0	6.0	3.8	4.39	4.71	1.07	.185	2,275
80	Aug. 2	0.09	...	.0180	.0004	.0001	1184	1.15	9.7	...	3.9	4.35	5.40	0 88	.085	725
89	" 5	0.10	...	.0232	.0007	.0001	.0815	1.40	13.0	4.0	3 6	4.84	6.15	1.08	.120	750
101	" 10	0.06	...	.0200	.0018	.0000	.0592	1.73	10.8	...	2.1	5.96	6.98	1.03	.060	575
111	" 12	V. t'd	...	.0250	.0028	.0000	.0740	2.21	24.8	13.6	5.4	6.24	6.30	1.27	.420	.....
128	" 18	0.12	...	.0360	.0018	.0000	.0375	1.62	26.0	16.0	5.0	6.65	4.50	1.00	.620	2,075
151	" 24	Slight	...	.0215	.0025	.0000	.1125	1.70	7.2	1.0	4.8	5.45	3.65	1.13	.010	1,150
162	" 26	"	.50	0180	.0006	.0000	.1050	1.71	11.0	0.2	4.6	5.68	4.00	1.07	.060	1,325
169	" 30	0.02	.40	.0158	.0016	.0000	.0225	1.55	10.4	...	4.8	4.35	4.09	1.37	.040	2,362
	Av'gs,	0.08	.45	.0222	.0015	.0000	.0763	1.63	14.1	4.3	4.3	5.44	5.13	1.10	.177	1,280
190	Sept. 2	0.09	.40	.0170	.0025	.0000	.0600	2.52	11.6	...	2.4	5.60	4.45	1.20	.034	3,075
211	" 7	0.04	.30	.0164	.0011	.0000	.0300	1 91	10.0	...	4.5	5.49	4.88	1.41	.026	2,400
222	" 9	Slight	.40	.0146	.0016	.0000	.0450	2.05	12.0	...	4.0	5.64	5.05	1.72	.036	4,538
238	" 14	0.03	30	.0116	.0022	.0000	.0300	2.14	13.2	...	6.0	5.95	5.58	1.44	.016	1,545
247	" 16	0.04	.30	.0108	.0017	.0000	.0375	2.50	12.8	...	5 2	7.18	5.53	1.96	.044	1,650
253	" 20	0.05	.25	.0116	.0018	.0000	.0375	2.61	14.0	...	6.0	6.93	5.59	1.78	.030	1,225
273	" 23	0.05	.30	.0120	.0012	.0000	.0605	3 08	14.8	...	4.8	6.50	5.52	1.92	.068	3,125
287	" 27	Slight	.25	.0112	.0016	.0000	.0638	2.93	15.6	...	6.0	3.60	3.74	3.30	.060	1,750
304	" 30	0.08	.40	.0104	.0014	.0000	.0600	2.45	16.0	...	6.0	4.90	4.20	2.02	.078	4,549
	Av'gs,	0.05	.32	.0128	.0017	.0000	.0471	2.47	13.3	...	5.0	5.75	4.95	1.86	.044	2,651

Gate Chamber.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
321	Oct. 5	0.05	.35	.0140	.0014	.0000	.0750	2.98	16.0	...	7.2	4.80	4.32	2.58	.052	1,876
333	" 6	0.04	.30	.0180	.0018	.0000	.0938	2.80	16.8	...	6.0	5.48	5.20	2.16	.072	18,550
347	" 11	0.03	.30	.0164	.0014	0000	.0825	3.18	17.2	...	7.2	5.46	4.90	2.06	.056	13,700
362	" 14	0.03	.30	0162	.0024	.0000	.0600	3.26	18.0	...	8.4	5.08	4.77	2 15	.046	27,300
374	" 18	V.sl'gt.	.20	.0110	.0024	0000	.0900	3.59	16.0	...	6.0	5.58	5.09	2.54	.042	76,913
389	" 21	0.03	.20	.0120	.0012	.0000	.0375	3.84	16.8	...	6.8	5 16	4.97	2.54	.052	159,500
406	" 25	0.03	.25	0088	0020	.0000	.0375	3.81	18.0	...	7.2	5.06	4.89	2.85	.054	94,500
421	" 28	0.02	.20	.0168	.0016	.0000	.0600	3.80	18.8	...	4.0	5.80	5.24	2.92	.040	206,500
	Av'gs,	0.03	.26	0141	.0018	.0000	.0670	3.41	17.2	...	6.6	5.30	4.92	2.47	.052	74,855
433	Nov. 1	0.03	.25	.0090	.0018	.0000	.0150	3 90	19.2	0.3	5.2	5.63	5.39	3.09	058	111,000
453	" 4	0.04	.20	.0118	.0018	0000	.0675	4.75	21.6	0.0	7.2	5.82	5.62	2.48	.056	72,875
465	" 8	0.04	.20	0132	.0028	0000	.0450	4.36	22.8	0.4	8.4	4.98	4.71	3.85	.075	7,850
481	" 11	0.11	.30	.0170	.0024	.0000	.0225	3.43	22.8	0.6	7.8	3.68	3.42	4.54	.078	.....
501	" 18	0.88	.40	.0220	.0014	.0000	.0825	1.80	32.8	17.2	7.2	3.41	2 61	1.37	320	17,950
520	" 23	0.08	.40	.0126	.0008	.0000	.0825	2.03	12.8	0.5	4.8	2.90	2.31	1.11	.060	15.150
540	" 29	0.50	.30	.0180	.0010	.0000	.0750	1.63	16.8	6.0	6.0	2.64	2.07	0.89	.150	33,075
	Av'gs,	0.24	.29	.0148	0017	.0000	.0557	3.13	21.3	3.6	6.7	4.15	3.73	2.48	114	42,983
557	Dec. 6	0.36	.30	0086	.0010	0000	1500	1.40	23.6	12.0	8.4	1.42	1.15	2 16	.190	28,850
573	" 13	0 09	.30	.0088	.0022	.0000	1200	1.90	15 6	0.2	6.4	2.25	2.02	1.27	.120	7,800
593	" 20	0.13	.30	.0078	.0012	0000	.0450	1.41	12 4	2.0	6.0	1.64	1.36	1.10	.132	.....
609	" 28	0.06	.30	.0088	.0014	.0000	.0900	2.21	11.8	0.0	3 4	2.04	1.22	1.99	.060	1,900
	Avg's,	0.16	.30	.0085	.0014	.0000	.1012	1.73	15.8	3.5	6.1	1.84	1.44	1.63	.125	12,850
	1898.															
625	Jan. 3	0.04	.20	.0042	.0014	.0000	0750	1.95	12.0	0.0	3.6	2.90	2.18	2.13	.050	1,625
638	" 10	0.30	.30	.0076	.0012	.0000	.1350	1.64	18.8	6.8	6.8	2.20	1.91	1.58	.072	16,175
664	" 17	0.26	.30	.0080	.0010	.0000	.0900	1.21	15.2	5.2	4.4	1.86	1.51	1.44	.192	21,275
682	" 24	0.50	.30	.0098	.0010	.0000	0525	0.94	18.8	11.2	7.2	1.68	1.12	0.68	.200	26,150
698	" 31	0.08	.20	.0052	.0016	.0000	.1050	1.12	7.4	0.0	2 0	1.90	1.30	1.03	.076	2,350
	Av'gs,	0.24	.26	.0070	.0012	.0000	.0915	1.37	14.4	4.6	4.8	2.11	1.60	1.37	.118	13,515

Gate Chamber.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
718	Feb. 7	0.04	.20	.0050	.0014	.0000	.1650	1.66	13.2	0.0	5.8	3.22	2.49	1.34	.056	1,700
738	" 14	0.32	.30	.0108	.0018	.0000	.2025	1.30	18.4	9.4	3.2	2.41	1.33	0.61	.212	25,600
757	" 21	0.16	.27	.0210	.0014	.0000	...	1.21	10.8	0.4	3.6	2.90	1.70	1.33	.148	12,025
775	" 28	0.04	.20	.0058	.0012	.0000	.0525	1.00	8.4	0.0	1.6	2 66	1.92	1.32	.050	6,125
	Av'gs,	0.14	.24	.0106	.0014	.0000	.1400	1.29	12.7	2.4	3.5	2.80	1.86	1.15	.116	11,362
793	Mar. 7	0 04	.20	.0048	.0014	.0000	.0525	1.28	9.4	0.2	2.8	3.24	2.51	1.55	.040	5,100
813	" 14	0.11	.25	.0068	.0014	.0000	.0375	1.61	8.3	0.3	2.8	2.80	1 95	0.96	.020	12,025
828	" 21	0.90	.22	.0158	.0016	.0000	.0525	1.28	29.6	18.4	4.0	1.90	1.40	0.17	.158	.....
843	" 22	1.00	.25	.0126	.0088	.0000	.0600	0.86	54.0	40.9	9 2	3.82	2.70	4.57	.082	56,000
848	" 28	0.20	.25	.0110	.0016	.0000	.0450	0.89	9.5	0.4	4.0	2.66	1.00	1.06	018	4,750
	Avg's,	0.45	.23	.0102	.0030	.0000	.0495	1.18	22.2	12.0	4.6	2.88	1.91	1.66	.064	19,469
869	Apr. 4	0.08	.20	.0060	.0020	.0000	.0450	1.14	9.2	0.0	3.6	2 62	1.54	1.03	.027	2,937
888	" 11	0.04	.25	.0064	.0012	.0000	.0675	1.24	8.2	0.0	2 2	2.88	2 31	1.17	.050	3.037
907	" 18	0.05	.22	.0118	.0018	.0000	.0525	1.50	8.8	0.4	3 6	2.54	2.10	1.50	.055	2,525
925	" 25	0.20	.25	.0090	.0036	.0000	.0525	1.30	9.8	0.2	4 8	2.98	2.51	0.85	028	16,000
	Av'gs,	0.09	23	.0083	.0021	.0000	.0544	1.29	9.0	0.1	3.5	2.75	2.11	1.14	.040	6,125
945	May 2	0.03	.27	.0132	.0018	0000	.0225	1.36	8.2	0.2	2.8	2.64	2.24	0.34	.028	3,120
969	" 9	0.28	.27	.0120	0014	.0000	0225	1.13	14.2	4.6	4.2	2.68	1.90	1.16	.120	19,400
992	" 16	0.20	.25	.0122	.0010	.0000	.0075	2.32	13.2	3.2	3 4	3.12	2.60	0.52	.030	33,600
1022	" 23	0.15	.40	.0140	.0006	.0000	.0375	0.95	12.4	5.4	3.2	2.82	1.90	0.79	.016	13,900
1043	" 31	0.07	.27	.0068	.0006	.0000	.0600	1.21	7.0	0 0	3.6	2.68	2.30	0.89	.018	1,960
	Av'gs,	0.15	.29	.0116	.0011	.0000	.0300	1.39	11.0	2.7	3.4	2.79	2.19	0.74	.042	14,400
1066	June 6	0.02	.20	.0068	.0024	0000	.0300	2.14	9 0	0.0	3.6	3 20	2.95	0.75	.010	3,460
1085	" 13	0.03	.30	.0110	.0028	.0000	.0300	2.48	11.9	0.5	4.8	3.60	3.40	1.54	.004	21,200
1110	" 20	0.65	.30	.0110	.0012	.0000	.0225	1.54	36.8	26 8	4.8	3.30	3.24	0.92	.025	25,100
1136	" 27	0.07	.20	.0070	.0024	.0000	.0750	2.48	13.6	3.4	4.1	3 26	3.00	1.30	.012	3,770
	Av'gs,	0.19	.25	.0089	.0022	.0000	.0394	2.16	17.8	7.7	4.3	3.34	3.15	1.13	.013	13,400

Gate Chamber.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
1162	July 5	0.05	.27	.0130	.0026	.0000	.0750	1.45	9.4	1.0	4.1	3.56	2.90	0 24	.024	6,850
1187	" 11	0.04	.27	.0094	.0042	.0000	.0900	2.30	11.2	1.2	4.6	3.72	3.48	0.92	.030	3,850
1208	" 18	0.06	.30	.0088	.0022	.0000	.0600	3.34	14.7	1.3	4.8	5.45	4.10	1 82	.026	14,400
1237	" 25	0.06	.22	.0080	.0022	.0000	.0525	2.69	15.6	0.0	5.8	5.52	3.40	2.47	.008	8,750
	Av'gs,	0.05	.26	.0098	.0028	.0000	.0694	2.44	12.7	0.9	4.8	4.56	3.47	1.36	.022	8,450
1255	Aug. 1	0.70	.27	.0130	.0032	.0000	.0525	3.99	35.0	18.9	5.4	5 73	4.54	1.68	.028	27,500
1285	" 8	0.28	.25	.0122	.0024	.0000	.0450	2.60	22.6	9.8	4.5	3.98	3.56	1.34	.014	49,400
1315	" 15	0.12	.30	.0110	.0022	.0000	.0600	2.20	14.3	3.9	4 4	3.70	2.82	1.07	.020	4,800
1345	" 22	0.31	.30	.0100	.0024	.0000	.0225	1.32	15.6	8.2	3.4	2.80	1.96	0.61	.010	12,600
1377	" 29	0.09	.35	.0072	0024	.0000	.0450	1.65	11.0	2.4	3.8	3.92	2.92	0.34	.010	1,700
	Av'gs,	0.30	.29	.0107	.0025	.0000	.0450	2.35	19.7	8.6	4.3	4.03	3.16	1.01	.016	19,200

Gate Chamber. (Special.)

(PARTS PER 100,000.)

	1898.															
1016	May 18	1.08	...	...	...	...	...	...	113.0	104.4	3.3	...	2.05	...	...	17,000
1060	June 3	V.sl'gt.	.30	.0060	.0016	.0000	.0375	1.90	8.0	0.0	3.8	3.00	2.70	...	.014	3,020
1063	" 4	Slight	.30	.0062	.0018	.0000	.0225	2.17	8.9	0.6	3.8	2.80	2.73	0.85	.018	2,300
	Av'gs,	.....	.30	.0061	.0017	.0000	.0300	2.03	8.4	0.3	3.8	2.90	2.71	0.85	.016	2,660
1360	Aug. 20	1.75	.30	...	...	.0000	...	1.30	88.2	77.9	3.9	2.60	1.72	1.38	.016	25,000

SETTLING BASIN.

Samples from the "Settling Basin" were collected twice a week after the sand filters were placed in operation, until December 1, 1897. From that time until the close of the experiments samples were collected once a week.

These samples were collected at the surface of the water in the central well, from which the water was supplied to the filter using settled water.

Settling Basin.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897															
55	July 18	Slight	...	.0202	.0046	.0000	.0075	2.75	13.2	7.0	5.2	4.92	8.50	1.41	.040	.....
63	" 26	0.33	...	.0280	.0035	.0001	.1853	1.10	15 3	5.6	4.2	5.02	4.70	1.72	.230	1,450
73	" 29	Dec'd	...	.0220	.0013	.0000	.1297	1.25	13.5	3.9	3.7	4.25	4.94	1.19	.170	3,100
	Av'gs,	.....	...	.0234	.0031	.0000	.1075	1 70	14.0	5.5	4.4	4.73	6 05	1.44	.147	2,275
81	Aug. 2	0.09	...	0160	.0006	.0001	.1260	1.30	10.3	...	4.4	4.36	5.45	1.03	.070	1,000
90	" 5	0.07	...	.0204	.0020	.0001	.0741	1.30	9.2	1.3	3.6	4.92	6.20	1.10	.060	1,275
98	" 9	0.03	...	.0220	.0023	.0000	0518	1.20	10.9	0.6	4.1	5.53	6 20	1.38	.120	575
112	" 12	V. t'd	...	.0245	.0025	.0000	.0518	2.29	16.4	5.8	5.6	7.06	6.58	1.20	.200	.....
129	" 18	0.30	...	.0240	.0011	.0000	.0375	1.44	11.6	1.8	5.6	7.40	4.60	1.14	.160	2,025
152	" 24	Dec'd	...	.0220	.0016	.0000	.0937	2.37	13 2	0.8	6.0	6.42	3.82	0.96	.030	1,025
163	" 26	Slight	.50	.0185	.0006	.0000	.0450	1.74	10 0	...	4.0	5.57	3.92	0.87	.037	1,237
170	" 30	0.00	.40	.0156	.0014	.0000	.0600	1.59	10.0	...	4.8	4.40	4.22	1.16	.030	825
	Av'gs,	0.10	.45	.0204	.0015	.0000	.0675	1.65	11.4	1.3	4.8	5.71	5.12	1.10	.088	1,137
191	Sept. 2	0.04	.45	.0156	.0023	.0000	.0675	2.30	10.4	...	2.4	4.20	4.28	1.47	.034	975
212	" 7	0.03	.30	.0156	.0018	.0000	.0300	2.16	10.8	..	4.8	5.41	4.77	1.44	022	962
223	" 9	Slight	.30	.0160	.0034	.0000	0488	1.92	11.6	...	4.0	6.27	4.94	1.58	.010	3,100
239	" 14	0.04	.30	.0122	.0010	.0000	.0150	2.31	14.0	...	6.4	5.55	5.45	1.37	.020	720
248	" 16	0.03	.30	.0120	.0022	.0000	.0300	2.68	12.6	...	5.4	6.82	5.59	2.02	.036	225
254	" 20	0.04	.30	.0112	.0016	.0000	.0150	2.69	15.6	...	6.0	7.12	5.33	1.61	.040	1,041
274	" 23	0.04	.35	.0122	.0014	.0000	.0638	3.75	16.0	...	6.0	5.48	5.40	1.68	.074	2,275
288	" 27	V. sl'gt	.20	.0122	.0016	.0000	.0450	3.42	17.2	...	6.8	4.52	4.65	2.99	.054	1,112
305	" 30	0.06	.40	.0112	.0016	.0000	.0525	2.40	17.2	...	6.8	3.87	3.78	2.44	.070	2,200
	Av'gs,	0.04	.32	.0131	.0019	.0000	.0408	2.63	13.9	...	5.4	5.47	4.91	1.84	.041	1,401

Settling Basin.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
322	Oct. 5	0.04	.30	.0148	.0018	.0000	.1050	2.69	16.8	...	6.4	4.63	4.12	2.64	.062	2,237
334	" 6	0.03	.30	.0158	.0014	.0000	.1050	2.76	16.8	...	6.8	5.60	5.29	2.16	078	2,700
348	" 11	0.03	.25	.0142	.0016	.0000	.0750	2.81	16 8	...	7.2	5.31	4.80	2.09	.050	12,562
363	" 14	0.03	.30	.0158	.0026	.0000	.0600	2.98	17.2	...	6.4	5.16	4.78	2.05	.038	19,000
375	" 18	V. sl'gt	.20	.0106	.0018	.0000	.0825	3.61	16.0	...	6.8	5.02	4.98	2.47	.030	51,025
392	" 21	0.03	.20	.0116	.0014	.0000	.0375	3.92	15.6	...	6.0	5.22	5.03	2.20	.042	76,500
407	" 25	0.02	.20	.0090	.0012	.0000	.0450	3.81	16.8	...	6.0	5.16	5.02	2 75	.042	45,875
422	" 28	0.02	.20	.0146	.0016	.0000	.0525	3.52	20.0	...	8.8	4.98	4.84	2.51	.044	102,125
	Av'gs,	0.03	.24	0133	.0017	.0000	.0703	3.26	17.0	...	6.8	5.13	4.86	2.36	.048	39,003
434	Nov. 1	0.03	.20	.0098	.0018	...	...	3.64	18.8	0.0	6.4	5.40	5.23	...	.042	103,250
454	" 4	0.04	.20	.0110	.0044	.0000	.0750	5.12	21 6	0.0	7.2	5.88	5.65	2.51	.054	76,525
466	" 8	0.05	.15	.0120	.0022	.0000	.0450	4.28	21.6	0.0	9.2	4.78	4.56	3 95	.052	17,425
482	" 11	0.08	.25	.0164	.0014	.0000	.0300	5.15	23.6	0.7	10.0	5.06	4.89	2.75	.088	.....
502	" 18	0.50	.35	.0216	.0012	.0000	.0750	2.62	26.8	9.2	9.2	3.90	3.09	1.30	.360	24,400
521	" 23	0.10	.40	.0140	.0018	.0000	.0750	2.07	14.0	1.2	5.0	2.96	2.53	1.16	.110	24,350
541	" 29	0.44	.25	0184	.0016	.0000	.0600	2.15	16.4	4.0	6.8	2.98	2.20	1.29	.130	22,450
	Av'gs,	0.18	.26	.0147	.0021	.0000	.0600	3.58	20.4	2 2	7.7	4.42	4.02	2.16	.119	44,733
558	Dec. 6	0.10	.30	.0106	.0010	.0000	.1350	2.28	13.2	0.8	6.8	2.06	1.72	1.23	.110	16,925
574	" 13	0.08	.25	.0092	.0020	.0000	.0525	1.72	12.0	...	4.4	2.54	2 33	1 27	.118	11,325
594	" 20	0.18	.30	.0080	.0010	.0000	.0525	1.48	12.0	0.8	4.0	2.17	1.86	1.06	.116	18,500
610	" 28	0.05	.30	.0080	.0018	.0000	.0825	1.87	10.4	0.0	3.6	2.46	1.64	1.47	.064	5,050
	Av'gs,	0.10	.29	.0089	.0014	.0000	.0806	1.84	11.9	0.4	4.7	2.31	1.89	1.26	.102	12,950
	1898.															
626	Jan. 3	0.04	.10	.0046	.0016	.0000	.0900	1.99	12.0	0.0	4.0	2.08	1.82	2.16	.060	2,425
639	" 10	0.21	.30	.0068	.0016	.0000	.1425	1.70	15.6	3.8	4.8	2.42	1.96	1 78	.184	16,525
665	" 17	0.22	.30	.0078	.0014	.0000	.0900	1.18	13.2	3.2	4.4	1.92	1.60	1.23	.190	32,875
699	" 31	0.07	.20	.0054	.0012	.0000	.1050	1.01	7.2	0.0	2.0	1.84	1.29	0.86	.072	5,200
	Av'gs,	0.13	.22	.0061	.0014	0000	.1069	1 47	12.0	1.7	3.8	2.06	1.67	1.51	.126	14,256

Settling Basin.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
719	Feb. 7	0.03	.15	.0054	.0016	.0000	.1650	1.60	15.6	0.0	7.6	3.28	2.25	1.47	.054	1,775
739	" 14	0.19	.30	.0112	.0018	.0000	.2250	1.40	10.6	1.0	2.4	2.54	1.56	0.49	.136	33,600
758	" 21	0.10	.30	.0180	.0018	.0000	...	1.18	10.2	0.2	3.0	3.01	1.72	1.25	.098	11,375
776	" 28	0.06	.22	.0058	.0016	.0000	.0600	1.34	8.2	0.0	2.0	2.94	2.10	1.34	.065	13,825
	Av'gs,	0.09	.24	.0101	.0017	.0000	.1500	1.38	11 1	0.3	3.7	2.94	1.91	1.14	.088	15,144
794	Mar. 7	0.05	.25	.0048	.0014	.0000	.0525	1.48	10.2	0.2	3.4	3.04	2.34	1.34	.035	7,350
814	" 14	0.06	.22	.0056	.0010	.0000	.0375	1.64	10.2	0.2	3.2	3.06	2.20	1.20	.035	13,000
829	" 21	0.17	.17	.0138	.0016	.0000	0600	0.98	11.9	1.1	2.8	2.84	2 000	0.30	000	.....
849	" 28	0.16	.25	.0100	.0016	.0000	.0300	0.85	9.5	0.3	4.4	2.32	0.95	1.16	.022	7,316
	Av'gs,	0.11	.22	.0085	.0014	.0000	.0450	1.24	10.4	0.4	3.4	2.81	1.87	1.00	.038	9,222
870	Apr. 4	0.11	.20	.0064	.0020	.0000	.0450	1.07	9.6	0.0	4.0	2.60	1.50	0.86	.038	4,875
889	" 11	0.06	.20	.0070	.0018	.0000	.0525	1.30	7.2	0.0	2.2	2.60	2.10	1.31	.050	2,550
908	" 18	0.04	.20	.0120	.0028	.0000	.0300	1.82	9.8	0.2	3.0	2.66	2.22	1.65	.052	2,300
926	" 25	0.06	.22	.0084	.0038	.0000	.0450	1.62	9.8	0.2	3.2	2.90	2.47	1.20	.040	7,150
	Av'gs,	0.07	.20	.0084	.0026	.0000	.0431	1.45	9.1	0.1	3.1	2.69	2.07	1.25	.045	4,219
946	May 2	0.04	.25	.0104	.0014	.0000	.0225	1.28	8.4	0.0	3.2	2.30	2.05	0.34	.032	3,100
970	" 9	0.14	.25	.0080	.0012	.0000	.0300	1.28	12.0	3.2	4.0	3.12	2.14	1.07	.095	5,550
993	" 16	0.06	.22	.0060	.0012	.0000	.0075	1.68	9.0	0.4	3.8	2.60	2.31	1.00	.018	6,450
1027	" 23	0.15	.30	.0138	.0012	.0000	.0300	1.00	10.2	2.6	3.3	2 30	2.10	0.68	.028	6,400
1053	" 31	0.05	.35	.0060	.0008	.0000	.0375	1.26	7.0	0.0	3.3	2.60	2.32	0.85	.025	1,800
	Av'gs,	0.09	.27	.0088	.0012	.0000	.0255	1.30	9.3	1.2	3.5	2.58	2.18	0.79	.040	4,660
1067	June 6	0.03	.20	.0070	.0016	.0000	.0225	2.10	9.0	0.0	3.8	3.08	2.65	0.71	.016	2,250
1086	" 13	0.03	.27	.0098	0024	.0000	.0225	2.30	10.6	0 0	4.2	3.40	3.26	1.16	.002	5,500
1115	" 20	0.27	.30	.0098	.0020	.0000	.0225	1.70	17.2	7.2	3.8	3.52	3.00	1.13	.022	12,600
1137	" 27	0.07	.17	.0068	.0022	.0000	.0525	2.38	12.0	2.0	4.2	3.08	2.92	0.82	.016	2,500
	Avg's,	0.10	.23	.0083	.0020	.0000	.0300	2.12	12.2	2.3	4.0	3.27	2.96	0.95	.014	5,700

Settling Basin.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
1163	July 5	0.06	30	.0120	.0020	.0000	.0825	1.50	8.6	0.4	4.0	3.00	2.88	0.55	.020	1,370
1188	" 11	0.03	20	.0096	.0042	.0000	.0675	2.34	13.2	3.4	4.6	3.60	3.41	0.38	.036	2,000
1209	" 18	0.15	27	.0080	.0022	.0000	.0600	4.20	20.3	5.1	5.8	6.15	3.90	1.88	.022	18,100
1238	" 25	0.06	20	.0086	.0022	.0000	.0450	2.63	16.4	0.0	5.4	5.68	3.00	3.40	.006	11,500
	Av'gs,	0.07	24	.0095	.0026	.0000	.0637	2.67	14.6	2.2	4.9	4.61	3.30	1.55	.021	8,250
1256	Aug. 1	0.50	25	.0110	.0030	.0000	.0600	4.35	31.8	15.4	5.6	5.94	4.50	1.47	.022	28,700
1286	" 8	0.22	20	.0128	.0026	.0000	.0525	2.64	17.6	3.9	4.4	3.90	3.42	1.27	.012	11,100
1316	" 15	0.16	30	.0098	.0016	.0000	.0675	2.22	13.2	2.8	4.6	3.50	2.76	1.03	.020	4,150
1346	" 22	0.22	40	.0104	.0024	.0000	.0225	1.40	11.8	3.7	3.4	2.88	1.90	1.00	.010	5,450
1378	" 29	0.08	28	.0078	.0024	.0000	.0450	1.62	9.0	1.4	3.0	3.62	2.82	0.32	.010	1,600
	Av'gs,	0.24	29	.0104	.0024	.0000	.0495	2.45	16.7	5.4	4.2	3.97	3.08	1.02	.015	10,200

EFFLUENTS —SAND FILTERS.

Samples of the "Effluents" from the "Sand Filters" were collected twice a week until December 1, 1898, and once a week from that time, until the close of the experiments.

These samples were collected from quarter-inch petcocks tapped into the effluent pipes from the sand filters.

Sand Filter No. 1.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
56	July 18	.....	...	.0175	.0139	.0002	.0465	3.81	64.1	3.0	21.4	7.08	10.20	1.06	.140	...
65	" 26	Slight	...	.0240	.0013	.0000	.1780	1.16	11.9	0.3	4.2	6.25	8.96	1.69	.150	750
74	" 29	"	...	.0136	.0000	.0001	.1483	1.10	10.6	0.2	3.7	6.45	8.21	1.03	.090	500
	Av'gs,	.....	...	.0184	.0051	.0001	.1243	2.02	28.9	1.2	9.8	6.59	9.12	1.26	.127	625

Sand Filter No. 1.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
82	Aug. 2	V. sl'gt	..	.0100	.0001	.0004	.1260	1.20	12.0	...	4.9	6.85	9.85	1.07	.045	104
91	" 5	V. "	...	.0080	.0001	.0003	.0889	1.23	10.0	...	3.8	6.71	8.81	1.08	.045	54
99	" 9	Clear	...	.0086	.0014	.0000	.0740	1.28	11.2	...	3.7	8.70	8.92	1.19	.080	16
113	" 12	"	...	.0106	.0014	.0000	.0592	2.01	10.2	...	3.4	9.50	8.77	1.20	.012	...
130	" 18	"	...	.0115	.0009	.0000	.0300	1.46	9.8	...	5.2	8.16	5 51	1.17	.040	44
153	" 24	V. sl'gt	...	.0115	.0017	.0000	.0900	1.15	9.2	...	2.0	6.76	4.99	0.86	014	35
164	" 26	V. "	.40	.0106	.0005	0000	.0525	1.91	10.4	...	4.0	6.13	5.14	0.68	.024	21
171	" 30	Slight	.30	.0096	.0014	.0000	.0450	1.82	9.6	...	4.0	5.59	5.29	1.30	010	21
	Av'gs,	.....	.35	.0100	.0009	.0001	.0707	1 51	10.3	...	3.9	7.30	7.16	1.07	.034	42
192	Sept. 2	Clear	.20	.0088	.0016	.0000	.0600	2.00	10.2	...	4.0	7.40	5.76	1 58	.014	26
213	" 7	"	.10	0072	.0012	.0000	.0450	1.92	12.0	...	4.4	6.05	5.81	1.30	.008	13
224	" 9	"	.20	.0084	.0012	.0000	.0525	2.11	12.4	...	4.4	6.60	5.93	1.54	.010	10
240	" 14	"	.05	.0084	.0010	.0000	.0450	2.15	14.0	...	5.2	6.69	6.38	1.58	.004	6
249	" 16	"	.00	.0080	.0026	0000	.0358	2.36	13 8	...	5.2	7.34	7.03	2.06	.001	15
255	" 20	.....	.00	.0064	0008	.0000	0300	2.50	14.8	...	5.6	7.65	6.29	1.85	.001	27
275	" 23	Clear	.00	.0068	.0010	0000	.1125	3.11	14.6	...	5.6	5.92	6.35	1.85	.002	19
289	" 27	"	.00	.0068	.0020	.0000	0562	3.26	17.2	...	6.8	5.76	5.90	2.78	.002	18
306	" 30	"	.00	.0076	.0016	.0000	.0562	2.47	15.6	...	6.0	5.28	5.15	2.64	.014	14
	Av'gs,	.....	.06	.0076	.0014	.0000	.0548	2.43	13.8	...	5.2	6.52	6.07	1.91	.006	16
323	Oct. 5	Clear	.00	.0088	.0018	.0000	.1200	2.75	16.8	...	5.6	5.90	5.02	2.68	.008	15
335	" 6	"	.00	.0096	.0016	.0000	.1500	2.60	16.4	...	5.6	6.77	6.46	2.09	.020	15
349	" 11	"	.00	.0066	.0016	.0000	.0900	2.80	17.2	...	6.4	5.70	5.20	2,12	.006	84
364	" 14	"	00	.0084	.0028	.0000	.0675	3.12	17.6	...	6.8	5.80	5.35	2.41	.001	26
376	" 18	"	.00	.0064	.0014	.0000	.0900	3.45	16.0	...	6.8	6.00	5.92	2.71	.002	25
393	" 21	"	.00	.0062	.0016	.0000	.0450	3.21	18.0	...	7.6	5.70	5.50	2.58	.002	17
408	" 25	"	.00	.0046	.0010	0000	.0450	3.56	18.0	...	7.0	5.88	5.68	2.81	.004	22
423	" 28	"	.00	.0120	.0018	.0000	.0450	3.48	19.6	...	7.6	6.13	5.64	2.75	.004	51
	Av'gs,	.....	.00	.0078	.0017	.0000	.0816	3.12	17.4	...	6.7	5.99	5.60	2.52	.006	32

Sand Filter No. 1.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
435	Nov. 1	Clear	.00	.0082	.0014	.0000	.0300	3.50	20.4	0.0	8.4	6.39	6.15	2.85	.003	45
455	" 4	"	.00	.0076	.0016	.0000	.0750	5.08	23.0	0.0	9.0	6.38	6.14	2.51	.004	26
467	" 8	"	00	.0068	.0022	.0000	.0825	4.66	22.4	0.0	9.0	5.80	5.53	3.78	.004	26
483	" 11	"	.00	.0110	.0016	.0000	.0600	5.41	22.4	0.0	8.8	5.72	5.41	2.42	.004	...
503	" 18	Slight	15	.0140	.0012	.0000	.0750	2 82	16.8	0.0	7.6	4.13	3.82	1 82	.066	1,701
522	" 23	V. slg't	30	.0086	.0002	.0000	.1500	1 95	11.2	0.0	3.2	3.48	3.19	1.10	.042	383
542	" 29	V. "	.25	.0120	.0018	.0000	.0675	1.90	13.2	0.0	5.2	3.20	2.92	1.13	.044	137
	Av'gs,	.....	.10	.0097	.0014	.0000	.0771	3.62	18.5	0.0	7.3	5.01	4.74	2.23	.024	386
559	Dec. 6	Clear	.00	.0074	.0016	.0000	.1425	2.32	12.4	0.0	4.4	3.28	2.80	1.44	.036	126
575	" 13	"	.00	.0048	.0018	.0000	.1050	1.81	12.4	0.0	5.6	3.18	2.83	1.27	.034	81
595	" 20	V. sl'gt	.10	.0060	.0010	.0000	.0600	1.67	10.0	0.0	4.0	2.88	2.41	1.13	.030	...
611	" 28	V. "	.00	.0044	.0018	.0000	.0675	1.81	12.0	0.0	3.2	3.70	3.19	1.61	.026	93
	Av'gs,	.....	.02	.0056	.0015	.0000	.0937	1.90	11.7	0.0	4.3	3.26	2.81	1 36	.031	100
	1898.															
627	Jan. 3	Clear	.00	.0044	.0012	.0000	.0675	2.00	12.8	0.0	4.8	3.24	2.85	2.13	.024	202
640	" 10	"	.00	.0038	.0010	.0000	.1650	1.74	10 8	0.0	2.4	4.64	4.08	1.85	.014	385
666	" 17	.074	.10	.0062	.0010	.0000	.1200	1.16	10.4	0.0	3.2	2.52	2.05	1.44	.042	510
683	" 24	.045	.27	.0060	.0010	.0000	.0675	0.86	8.0	0.0	4.8	2.84	2.18	1.10	.046	297
700	" 31	.011	.22	.0040	.0014	.0000	.0900	1.21	7.6	0.0	2.2	2.43	2.01	1.10	.016	152
	Av'gs,	.043	.12	.0049	.0011	.0000	.1020	1.39	9.9	0.0	3.5	3.13	2.63	1.52	.028	309
720	Feb. 8	Clear	.00	.0036	.0012	.0000	.1800	1.72	14.8	0.0	6.0	3.84	3.09	1.65	.020	119
740	" 14	.023	.22	.0052	.0016	.0000	.2400	1.62	9.6	0.0	2.8	2.64	2.82	0.86	.046	710
759	" 21	.010	.20	.0182	.0014	.0000	...	1.14	10.0	0.0	3.4	3.28	2.34	1.13	.015	133
777	" 28	.010	.00	.0040	.0012	.0000	.0675	1.30	9.2	0.0	2.8	3 16	2.48	1.26	.030	122
	Av'gs,	.014	.10	.0077	.0013	.0000	.1625	1.44	10.9	0.0	3.7	3.23	2.68	1.22	.028	271
795	Mar. 7	.001	.00	.0032	.0022	.0000	.0600	1.39	10.4	0.0	4.0	3.88	3.00	1.55	.024	38
815	" 14	.006	.00	.0036	.0012	.0000	.0450	1.48	8.0	0.0	3.6	4.32	3.32	1.34	.015	39
830	" 21	.010	.00	.0060	.0012	.0000	.0675	1.05	10.0	0.0	3.6	2.99	2.55	0.30	.010	...
850	" 28	.004	.00	.0034	.0020	.0000	.0375	1 02	9.6	0.0	4.4	3.19	2.09	1.03	.014	94
	Av'gs,	.006	.00	.0040	.0016	.0000	.0525	1.23	9.5	0.0	3.9	3.59	2.74	1.05	.016	57

Sand Filter No. 1.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
871	Apr. 4	.010	.00	.0048	.0010	.0000	.0525	1.18	8.8	0.0	3.2	3.18	2.41	0.86	.008	31
890	" 11	.001	.00	.0062	.0020	.0000	.0600	1.21	7.6	0.0	2.4	2.98	2.56	1.23	.016	25
909	" 18	Clear	.00	.0038	.0018	.0000	.0300	2.10	9.2	0.0	3.6	3.80	3 14	1.38	.008	30
927	" 25	.001	.10	.0052	.0038	.0000	.0450	1.76	9.2	0.0	3.2	3.90	3.40	1.10	.010	26
	Av'gs,	.004	.02	.0050	.0021	.0000	.0469	1.56	8.7	0.0	3.1	3.46	2.88	1.14	.010	28
947	May 2	.001	.10	.0052	.0018	.0000	.0300	1.22	7.6	0.0	3.2	3.80	3.27	0.58	.008	130
971	" 9	.002	.05	.0062	.0012	.0000	.0150	1.60	8.4	0.0	2.5	4.92	3.40	1.13	.008	77
994	" 16	.009	.00	.0052	.0010	.0000	.0150	1.41	9.0	0.0	2.6	3.90	3.36	0.75	.018	64
1023	" 23	.025	.20	.0038	.0006	.0000	.0375	1.03	8.4	0.0	3.4	4.10	3.19	0.79	.013	110
1044	" 31	.018	.12	.0038	.0006	.0000	.0375	1.28	8.0	0.0	3.8	3.90	3.30	1.03	.011	87
	Av'gs,	.011	.09	.0048	.0010	.0000	.0270	1.31	8 3	0.0	3.1	4.12	3.30	0.86	.012	94
1068	June 6	.012	.05	.0068	.0018	.0000	0225	2.20	9.8	0.0	3.9	4.66	4.00	0.82	.004	130
1087	" 13	.005	.00	.0068	.0018	.0000	.0300	2.45	11.6	0.0	3.8	4.66	4.42	1.27	.001	92
1111	" 20	.015	.10	.0044	.0008	.0000	.0300	1.70	11.6	0.0	4.2	4.20	3.90	1.03	.006	75
1138	" 27	.008	.10	.0048	.0022	.0000	.0825	2.20	12.0	0.0	4.9	4.16	4.10	0.92	.004	49
	Av'gs,	.010	.06	.0057	.0016	.0000	.0412	2.14	11.2	0.0	4.2	4.42	4.10	1.01	.004	86
	1898.															
1164	July 5	Clear	.10	.0100	.0024	.0000	.0825	1 58	9 8	0.0	4.4	4.42	4.36	0.34	.008	45
1189	" 11	.002	.10	.0040	.0028	.0000	.0975	2.30	11.2	0.0	4.0	4.76	4.72	0 92	.004	49
1210	" 18	Clear	.05	.0048	.0020	.0000	.0600	3.84	17.0	0.0	6.4	7.48	5.70	1.95	.006	290
1239	" 25	.001	.10	.0034	.0020	.0000	.0525	2.68	18.8	0.0	6.2	7.23	3.90	3.44	.002	43
	Av'gs,	.001	.09	.0055	.0023	.0000	.0731	2.60	14.2	0.0	5.2	5.97	4.67	1.66	.005	107
1257	Aug. 1	.000	.05	.0040	.0022	.0000	.0525	4.60	16.9	0.0	4.8	7.60	5.62	1.27	.006	52
1287	" 8	.000	.10	.0040	.0020	.0000	.0375	2.76	16.0	0.0	4.4	5.22	4.68	1.85	.002	85
1317	" 15	.007	.10	.0048	.0008	.0000	.0600	2.45	11.7	0.0	4.5	4.94	4.34	0.85	.004	40
1347	" 22	.017	.32	.0064	.0020	.0000	.0300	1.30	9.2	0.0	3.8	4.68	3.48	1.13	.002	67
1379	" 29	.010	.05	.0058	.0040	.0000	.0525	1.68	8.6	0.0	3.2	4.33	3.72	0.49	.004	52
	Av'gs,	.007	.12	.0050	.0022	.0000	.0465	2.56	12.5	0.0	4.1	5.36	4.37	1.12	.004	59

Sand Filter No. 2.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
57	July 18	.....	...	.0233	.0209	.0001	.0750	2.56	47.4	7.9	8.1	3.75	40.50	1.82	.100	...
60	" 23	V. sl'gt	...	.0122	.0018	.0005	0180	2.60	23 5	7.5	7.4	11 20	29.70	3.68	.250	8,820
66	" 26	Slight	...	.0160	.0009	.0000	.2220	1.15	13.8	1.9	3.6	7.37	9.75	1.32	.085	1,450
75	" 29	V. sl'gt	...	.0116	.0001	.0000	.1483	1.30	11.1	0.3	3.7	6.68	8.64	1.15	.085	250
	Av'gs,	.....	...	.0158	.0059	.0001	.1158	1.90	23.9	4.4	5.7	7.25	22.15	1.99	.130	3,507
83	Aug. 2	V. sl'gt	...	.0110	.0001	.0000	.1260	1.12	11.1	...	3.9	5.80	8.50	1.17	.075	66
92	" 5	V. "	...	.0085	.0001	.0000	.0750	1.27	10.2	...	3.9	8.05	9.04	1.17	.045	50
100	" 9	Clear	...	.0080	.0010	.0000	.0888	1.22	11.2	...	3.9	9.30	9.11	1.24	.080	34
114	" 12	"	...	.0095	.0012	.0000	.0592	2.44	11.2	...	5.4	7.91	8.81	1.37	.014	...
131	" 18	"	...	.0136	.0010	.0000	.0300	1.31	10.4	...	5.2	8.67	6.04	1.24	.030	22
154	" 24	V. sl'gt	...	.0098	.0016	.0000	.0937	1.78	9.8	...	2.6	7.14	5.08	0.79	.014	36
165	" 26	V. "	.40	.0114	.0005	.0000	.0750	1.79	10.4	...	4.4	6.38	5.41	1.03	.022	18
172	" 30	V. "	.30	.0092	.0014	.0000	.0600	1.73	9.6	...	4.0	5.56	5.60	1.37	.008	17
	Av'gs,	.....	.35	.0101	.0009	.0000	.0760	1.58	10.5	...	4.2	7.35	7.20	1.17	.036	35
193	Sept. 2	Clear	.20	.0075	.0014	0000	.0600	1.93	10.4	...	4.4	7.25	5.68	1.47	.008	47
214	" 7	"	.10	.0076	.0014	.0000	.0375	1.98	10 4	...	4.4	6 49	6.09	1.20	.007	7
225	" 9	"	.20	0092	.0006	.0000	.0562	1.97	13.0	...	4.8	6.94	5.22	1.70	.004	9
241	" 14	"	.05	.0078	.0008	.0000	.0300	2.11	13.8	...	5.0	7.69	7.10	1.72	.005	4
250	" 16	"	.00	.0064	.0032	.0000	.0450	2.33	14.0	...	5.6	7.20	6.99	1.96	.001	27
256	" 20	"	.00	.0076	.0010	.0000	.0300	2.64	14 4	...	5.6	7.15	6.49	1.85	.001	13
276	" 23	"	.00	.0076	.0014	.0000	.1050	3.05	15.2	...	5.2	6.52	6 61	2.13	.001	41
290	" 27	"	.00	.0074	.0022	.0000	.0562	3.37	18.0	...	6.4	4.87	4.95	3.80	.001	7
307	" 30	Slight	.00	.0090	.0014	.0000	.0600	2.20	15.0	...	5.8	5.58	5.50	2.27	.010	10
	Av'gs,	.....	.06	.0078	.0015	.0000	.0533	2 40	13.8	...	5.2	6.63	6.07	2.01	.004	18
324	Oct. 5	Clear	.00	.0080	.0012	.0000	.1050	2.86	15.2	...	5.2	6.21	5.28	2.58	.010	19
336	" 6	"	.00	.0108	.0016	.0000	.0825	2.75	16.8	...	6.0	7.06	6.90	2.40	.016	10
350	" 11	"	.00	.0076	.0012	.0000	.0825	2.76	17.6	..	5.6	6.13	5.65	2.23	.004	12
365	" 14	"	.00	.0092	.0030	.0000	.0675	3 05	18.0	...	7.6	5.92	5.55	2.50	.001	16
377	" 18	"	.00	.0068	.0014	.0000	.0975	3 52	17.2	...	6.8	5.60	5.48	2.78	.002	18
394	" 21	"	.00	0064	0014	.0000	.0450	3.28	18.8	...	6.8	5.98	5.70	2.68	.002	22
409	" 25	"	.00	.0044	.0008	.0000	.0525	3.62	21.2	...	8.8	6.04	5.90	2.78	.004	25
424	" 28	"	.00	.0124	.0018	0000	.0450	3.56	18.2	...	7.6	6.02	5.50	2.44	.004	26
	Av'gs,	.....	.00	.0082	.0015	.0000	.0722	3.17	17.9	...	6.8	6.12	5.74	2 55	.005	18

Sand Filter No. 2.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897															
436	Nov. 1	Clear	.00	.0040	.0016	.0000	.0375	3.66	20.8	0.0	8 8	6.70	6.55	2.99	004	40
456	" 4	"	00	.0080	.0016	.0000	.0675	4.73	23.2	0.0	9.2	7.30	7.03	2.58	.004	49
468	" 8	"	.00	.0070	.0024	.0000	.0675	4.14	22.3	0.0	8.0	5 60	5.32	3 88	.004	242
484	" 11	"	.00	.0106	.0016	.0000	.0525	4.78	21.6	0.0	9.6	6.16	5.91	2.61	.008	.....
504	" 18	Slight	.10	0152	.0014	.0000	.0825	1.70	14.8	0.0	6.4	4.03	3.18	1.58	.074	5,479
523	" 23	V. sl'gt	.30	.0080	.0004	.0000	.1425	1.97	12.4	0.0	4.8	3.67	3.43	0.99	.032	214
543	" 29	V "	.25	.0108	.0016	.0000	.0825	2.50	13.6	0.0	4.8	6.24	5.89	1.27	.038	511
	Av'gs,	.....	.09	.0091	.0015	.0000	.0761	3.35	18.4	0.0	7.4	5.68	5 33	2.27	.023	1,089
560	Dec. 6	Clear	.00	.0086	.0014	.0000	.0450	2.61	12.0	0.0	5.2	3 41	2.84	0.89	.034	144
576	" 13	"	.05	.0076	.0012	.0000	.1200	1.76	12.0	0 0	6.0	3 34	2.98	1.44	.032	145
596	" 20	V. sl'gt	.10	.0054	.0012	.0000	.0600	1.40	10.4	0.0	3.2	2.94	2.44	1.10	.030	.....
612	" 29	Clear	.00	.0040	.0010	.0000	.0675	1.78	11.6	0.0	3.6	3.14	2.79	1.72	.020	347
	Av'gs,	.....	.04	.0064	.0012	.0000	.0731	1.89	11.5	0.0	4.5	3.21	2.76	1.29	.029	212
	1898.															
628	Jan. 3	Clear	.00	.0048	.0014	.0000	.0750	1.92	14.8	0.0	6.0	5.22	4 15	2 16	.018	352
641	" 10	"	.00	0032	.0012	.0000	.1575	1.96	12 4	0.0	2.8	3.98	3 37	1.75	.022	449
667	" 17	.015	.10	0058	.0012	.0000	.1125	1.18	10.2	0 0	3.4	2.80	2.30	1.34	.030	366
684	" 24	.045	.25	.0046	.0008	.0000	.0600	0.88	8.0	0 0	4.7	2.61	2.09	1.10	.046	613
701	" 31	.011	.22	.0044	0014	0000	.1200	1.18	8.0	0.0	3.2	2.74	2.30	1 03	.010	.....
	Av'gs,	.024	.11	.0046	.0012	.0000	.1050	1.42	10.7	0.0	4.0	3.47	2.84	1.48	.025	445
721	Feb. 7	Clear	.00	.0034	.0012	.0000	.1725	1.66	14.8	0.0	6.4	3.66	2.82	1.61	050	118
741	" 14	.015	.17	0062	.0018	.0000	0060	1.47	10.2	0.0	3.0	3.88	3.10	0.86	.040	511
760	" 21	.015	.17	.0158	.0016	.0000	...	1 19	10.0	0.0	3.6	3.21	2 38	1.13	.050	307
778	" 28	.010	.00	0038	.0012	0000	0675	1.33	9.2	0.0	3.2	3.24	2.80	1.28	.025	201
	Avg's,	.013	.08	.0073	.0014	.0000	.1000	1.41	11.0	0.0	4.0	3.50	2.77	1.22	041	284
796	Mar. 7	.006	.00	0028	.0020	.0000	.0600	1.40	10.4	0.0	4.0	4.00	3.20	1.62	.026	81
816	" 14	.015	.00	0032	0012	0000	.0450	1.18	8.2	0.0	3.8	4.28	3.20	1.23	.015	109
831	" 21	.022	05	.0058	0020	.0000	.0600	1.15	9.6	0.0	3.6	3.16	2.80	0.27	.038	...
	Av'gs,	.014	.02	.0039	.0017	.0000	.0550	1 24	9.4	0.0	3.8	3.81	3.07	1.04	.026	95

Sand Filter No. 2.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
872	Apr. 4	.015	.00	0050	.0008	0000	.0525	0 95	8 4	0.0	2.8	3 22	2.40	0.99	025	116
891	" 11	.001	.00	.0056	0020	.0000	.0675	1.40	7.6	0.0	3.2	3.44	2.99	1.13	.008	81
910	" 18	Clear	.00	.0032	.0018	.0000	.0375	1.52	9.6	0.0	3 6	3.64	3.00	1.54	.008	64
928	" 25	.001	.07	.0048	.0040	.0000	.0300	1.80	8.8	0.0	2.4	4.18	3.70	0 92	.008	46
	Av'gs,	.006	.02	.0046	0021	.0000	.0469	1 42	8.6	0.0	3.0	3.62	3.02	1.14	.012	77
948	May 2	.001	.05	.0052	.0016	.0000	.0225	1.20	8.0	0.0	3.2	3.77	3.10	0.49	.008	50
972	" 9	.006	.05	.0054	.0014	0000	.0225	1.22	7.8	0.0	1.8	3.68	3.12	1.34	.008	41
995	" 16	.007	.10	.0058	0010	.0000	.0075	1.50	8 8	0.0	2.8	3.68	3.60	0.52	010	180
1024	" 23	.028	20	0036	.0008	.0000	.0300	1.02	8.2	0.0	4 0	3.70	3.37	0.52	.020	71
1045	" 31	.015	.12	.0032	.0006	.0000	.0450	1.32	8.2	0.0	3.8	4.21	3.41	0.85	.009	44
	Av'gs,	.011	.10	.0046	.0011	.0000	.0255	1.25	8.2	0.0	3.1	3.81	3.32	0.74	.011	77
1069	June 6	.009	.00	.0060	.0014	.0000	.0300	1.90	10 0	0.0	2.8	4.80	4.20	1.00	.002	120
1088	" 13	.005	.05	.0070	0022	.0000	0225	2.21	11.6	0.0	4.4	4.72	4.50	1.33	.001	52
1112	" 20	.022	.10	.0058	.0006	.0000	.0225	2.10	11.8	0.0	4.7	4 40	4.21	0.85	.008	38
1139	" 27	.013	.05	.0052	.0016	.0000	.0525	2.42	12.4	0.0	4.2	4.40	4.28	0.95	.002	76
	Av'gs,	.012	.05	.0060	.0014	.0000	.0319	2.16	11.4	0.0	4.0	4 58	4.30	1.04	.003	71
1165	July 5	Clear	.10	.0098	.0028	.0000	0900	1.56	9.6	0.0	4.4	4.10	4.00	0.17	.006	110
1190	" 11	.002	.05	.0044	.0028	0000	.0900	2.00	10.8	0.0	4.0	4.68	4.52	1.00	.004	104
1211	" 18	.000	.05	.0050	.0020	.0000	.0675	3.28	15.8	0.0	5.7	7.14	5.10	1.88	004	57
1240	" 25	.001	.05	.0036	.0020	.0000	.0600	2.66	18.0	0 0	5.4	7.17	3.94	3.13	002	62
	Av'gs,	.001	.06	.0057	.0024	0000	.0769	2.37	13.5	0.0	4.9	5.77	4.39	1.54	.004	83
1258	Aug. 1	.000	.05	.0042	.0016	0000	.0450	4.52	17.0	0.0	4 8	7.32	5.41	1.72	.004	55
1288	" 8	.000	10	0040	.0028	0000	.0525	2.68	15 3	0.0	5.1	5.04	4.20	2.06	.002	44
1318	" 15	.023	.10	.0050	.0030	.0000	.0675	2.75	11.2	0.0	4.0	4.68	3.90	1.23	.004	50
1348	" 22	.075	.40	0060	.0022	.0000	.0225	1.28	9.0	0.0	3.8	4.55	3.20	1.13	.004	240
1380	" 29	.015	.10	.0052	.0028	.0000	.0525	1.58	8.2	0.0	3.2	4.60	3.50	0.34	004	74
	Av'gs,	.023	.15	.0049	.0025	.0000	0480	2.56	12.1	0.0	4.2	5.24	4.04	1.30	.004	93

EFFLUENT—WARREN FILTER.

Samples of the "Effluent" from the "Warren Filter" were collected twice a week, from the time it was put into operation until June 1, 1898, and then once a week until the close of the experiments.

The samples were collected from a quarter-inch petcock, tapped into the effluent pipe between the filter basin and automatic weir. Samples were collected August 15 and August 29, 1898, from the water as it passed from the Settling Basin to the Filter.

Effluent—Warren Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
654	Jan. 13	V. sl'gt.	.20	.0062	.0050	0006	.1425	1 13	11.2	0.0	4.2	1.86	1.16	1.89	008	2,276
655	" 13	V. "	20	.0052	.0030	.0008	.1500	1.20	11.2	0.0	4.0	1.78	0.94	2 09	.008	2,276
676	" 20	.000	.00	.0040	.0020	.0000	.0750	1.35	10.4	0.0	5.2	1.60	1.00	1.10	.066	323
693	" 26	.000	.00	.0036	.0010	.0000	1200	0.90	8.0	0.0	4.0	1.90	0.51	1.10	.004	1,234
	Av'gs,	.000	.10	.0047	.0027	.0003	.1219	1.14	10.2	0.0	4.3	1.78	0.90	1.54	.021	1,527
702	Feb. 1	.000	.20	.0038	.0020	.0000	.0675	1.06	7.2	0.0	4 0	1.64	0.90	1.47	.010	128
709	" 3	.000	.12	.0038	.0014	.0000	.0600	1.50	7 6	0.0	2.6	2.14	1.53	1.03	.020	378
731	" 7	Clear	.00	.0032	.0022	.0000	.1500	1.78	6.8	0.0	2.4	2.20	1.49	1.72	.008	72
733	" 9	.000	.00	.0042	.0026	.0000	.1575	1 88	9.2	0.0	4.4	2.80	2.01	1.75	.010	...
742	" 14	.000	.05	.0060	.0020	.0000	.0450	1.17	7.0	0.0	2 0	2.12	1 01	1.13	.006	280
751	" 18	.000	.00	.0048	.0014	.0000	...	1.18	7.2	0.0	2.8	1.98	1.11	1.68	.004	265
761	" 21	.023	.00	.0164	.0018	.0000	...	1.20	8.4	0 0	2.8	1.43	0.86	1 72	.008	437
770	" 25	.000	.00	.0040	.0028	.0000	...	1.18	8.0	0.0	4.1	2.18	1.15	1.36	.006	115
779	" 28	.000	.00	.0032	.0016	.0000	.0450	1.12	8.0	0.0	2 8	1.90	1.04	1.89	.006	269
	Av'gs,	.003	.04	.0055	.0020	.0000	.0875	1.34	7.7	0.0	3.1	2.04	1.23	1.53	.009	243
786	Mar. 4	.000	.00	.0028	.0022	.0000	.0375	1.40	8.0	0.0	3.2	1.68	1.20	1.51	.008	55
799	" 7	.000	.00	.0028	.0016	.0000	.0525	1.31	8.4	0.0	2.0	2.80	1.70	1.82	.006	35
805	" 11	.000	.00	.0028	.0012	.0000	.0525	1.52	7.2	0.0	2.8	2.94	1.80	1 82	.006	450
819	" 14	.000	.00	.0030	.0014	.0000	.0525	1.06	6.4	0.0	2.4	2.00	1.10	0 89	.004	498
824	" 17	.000	.00	.0046	.0010	.0000	0450	1.20	5.4	0.0	1.6	1.94	1.22	0.72	.004	206
834	" 21	.003	.00	.0040	.0016	.0000	.0450	1.62	6.8	0.0	1.6	1.24	0.98	1.51	.016	...
841	" 25	Clear	.00	.0068	.0014	0000	0600	1.03	12.0	0.0	3.2	1.28	0.45	6.39	.006	88
853	" 28	.000	.00	.0044	.0016	.0000	.0450	1.20	8.0	0.0	2.0	1.62	0.74	1.37	.006	116
	Av'gs,	.000	.00	.0039	.0015	0000	.0487	1.29	7.8	0.0	2.3	1.94	1.15	2.00	.007	207

Effluent—Warren Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as.				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
862	Apr. 1	.000	.00	.0036	.0014	.0000	.0450	0.80	8.0	0.0	2.4	1.38	0.65	2.09	.004	220
875	" 4	.000	.00	.0042	.0012	0000	.0600	1.10	7 2	0.0	2.4	2.18	1.12	0.79	.008	100
882	" 8	.000	00	.0048	.0012	.0000	.0525	1.28	8.8	0.0	2.0	1.80	1.21	0.65	.008	106
892	" 11	.000	.00	.0042	.0012	.0000	.0600	1.28	6.8	0.0	1.6	2.18	1.60	1.65	.006	155
900	" 15	.000	.00	.0032	.0018	.0000	.0600	1.60	9.2	0.0	4.0	2.06	1 70	1.72	.006	45
911	" 18	Clear	.00	.0038	0022	.0000	.0300	1.40	8.8	0.0	3.6	2.16	1.71	2.03	.002	20
920	" 22	.000	.00	.0030	.0016	.0000	.0300	0.70	7.4	0.0	1.2	1.28	0.90	1.82	.002	39
929	" 25	.000	.00	.0042	.0026	.0000	.0375	1.42	8.8	0.0	3.2	2.64	2.13	1.30	.006	137
940	" 29	.000	.10	.0058	.0016	.0000	.0450	1.12	6.4	0.0	2.8	1.04	0.80	1.16	.004	34
	Av'gs,	.000	.01	.0041	.0016	0000	.0467	1.19	7.9	0.0	2.6	1.86	1.31	1.47	.005	95
949	May 1	.002	.12	.0060	.0008	.0000	.0300	1.30	7.6	0.0	2.8	2.08	1.78	0.21	.028	1,160
950	" 2	.002	.05	.0068	.0010	.0000	.0300	1.18	8.0	0.0	3.2	2.68	2.10	0.49	.024	900
960	" 3	.001	.05	.0050	.0020	.0000	.0075	1.30	6.0	0.0	2.0	2.33	2.01	0.31	.030	770
961	" 4	.002	.00	.0054	.0018	.0000	.0150	1.22	8.0	0.0	2.0	2.18	1.90	1.04	.024	560
963	" 5	.002	.10	.0054	.0022	.0000	.0225	1.30	8.8	0.0	2.8	2.68	2.15	0.58	.024	640
965	" 6	.015	.00	.0050	.0016	.0000	.0075	1.42	9.6	0.0	2.8	1 02	0.72	2.38	.004	52
966	" 7	.000	.05	.0048	.0018	0000	.0225	2.01	7.6	0.0	2.0	2.98	1.00	2.34	.002	62
973	" 9	.000	.00	.0056	.0016	.0000	.0225	0.98	9.6	0.0	3.2	3.62	0.42	3.03	.004	23
977	" 10	.000	.00	.0050	.0012	.0000	.0300	1.08	9.6	0.0	4.0	2.62	0.62	2.38	.002	13
985	" 12	.000	.05	.0034	.0016	0000	.0150	1.38	8.4	0.0	2.8	2.80	1.62	1.30	.002	12
987	" 13	.000	.00	.0040	.0012	.0000	.0225	1.50	8.4	0.0	2.4	3.01	1.30	1.75	.002	8
996	" 16	.011	.00	.0068	.0020	0000	.0075	2.30	8.6	0.0	2.4	3.25	2 00	1.20	.006	890
1005	" 16	.011	.15	.0064	.0008	.0000	.0075	1.42	9.2	0.0	3.2	3.20	2.00	1.72	.024	890
1025	" 23	.000	.00	.0040	.0006	.0000	.0375	0.87	7.2	0.0	3.0	2.80	0.58	1.95	.002	100
1046	" 31	.035	.20	.0048	.0004	.0000	.1500	1.38	6.6	0.0	3.6	2.60	2.03	0.96	.028	560
	Av'gs,	.005	.05	.0052	.0014	.0000	.0285	1.38	8.2	0.0	2.8	2.66	1.48	1.44	.014	445
1070	June 6	.000	.10	.0048	.0018	.0000	.0225	1.80	8.8	0.0	2.4	4.40	2.00	1.75	002	17
1091	" 13	.000	.05	.0046	.0016	.0000	.0450	2.50	11.1	0.0	3.0	4.88	2.40	2.12	.002	59
1113	" 20	.000	.05	.0040	.0010	.0000	.0150	1.70	9.9	0.0	3.8	3.65	1.50	2.24	.004	98
1140	" 27	.000	.05	.0064	.0016	.0000	.0450	2.46	11.0	0.0	3.9	3.30	2.50	1.61	.003	43
	Avg's,	.000	.06	.0049	.0015	.0000	.0319	2.11	10.2	0.0	3.3	4.06	2.10	1.93	003	54

Effluent—Warren Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
1166	July 5	Clear	.00	.0040	.0016	.0000	.0675	1.66	8 3	0.0	3.5	3.20	1.72	0.89	.002	2,300
1191	" 11	.000	00	.0052	.0018	.0000	.0750	2.20	10.2	0.0	3.6	3.90	2.54	2.09	.002	125
1212	" 18	.000	.00	.0044	.0020	.0000	.0675	3.10	16.0	0.0	5.2	4.40	3.00	3.09	.002	185
	Av'gs,	.000	.00	.0045	.0018	.0000	.0700	2.32	11.5	0.0	4.1	3.83	2.42	2.02	.002	870
1259	Aug. 1	.000	.05	.0054	.0024	0000	.0525	3.95	15.9	0.0	4.0	5.71	2.42	2.86	002	51
1289	" 8	.000	.05	0058	.0048	.0000	0525	2.68	13 2	0.0	3.8	4.02	2.33	1.75	.002	1,530
1319	" 15	.000	.05	.0048	.0040	.0000	0600	2.18	10.4	0.0	2.6	3.82	1.40	2.51	.002	86
1349	" 22	.000	.05	.0048	0024	.0000	.0225	1.36	7.7	0.0	2.6	2.92	0.40	2.38	.002	21
1381	" 29	.000	.05	.0048	.0022	.0000	.0375	1.52	11 2	3.0	2.8	3.64	1.70	1.44	.002	52
	Avg's,	.000	.05	.0051	.0032	.0000	.0450	2.34	11.7	0.6	3.2	4.02	1.65	2 19	.002	350
				Settled Water.												
1326	Aug. 15	Sl'gt	.15	...	...	...	...	2.25	14.4	3.6	3.4	3.58	1.95	1.75	.008	3,120
1383	" 29	Clear	.15	.0060	.0024	...	.0525	1.60	9.8	0.6	2.8	3.44	1.90	1.27	.010	1,370
	Av'gs,	...	.15	.0060	.0024	...	.0525	1.92	12.1	2.1	3.1	3.51	1.92	1.51	009	2,240

EFFLUENT—JEWELL FILTER.

Samples of the "Effluent" from the "Jewell Filter" were collected twice a week, from the time it was put into operation until June 1, 1898, and then once a week until the close of the experiments.

The samples were collected from a half-inch petcock, tapped into the effluent pipe between the filter basin and the gate. Samples were also collected August 15 and August 29, 1898, from the water as it appeared upon the surface of the filter.

Effluent—Jewell Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
677	Jan. 21	Clear	.00	.0042	.0014	.0000	.0450	0.98	10.2	0.0	4.8	1.68	1.05	1.54	.002	5,114
694	" 26	.000	.00	.0026	.0014	.0000	.1125	0.86	6.8	0.0	2.8	2.24	0.71	1.89	004	393
	Av'gs,	.000	.00	0034	.0014	.0000	.0787	0.92	8.5	0.0	3.8	1.96	0.88	1.71	.003	2,753
703	Feb. 1	.000	.10	.0030	.0020	.0000	.0600	0.98	7.2	0.0	4.2	1.91	0.93	1.47	.008	293
710	" 3	.000	.07	.0032	.0016	.0000	.0675	1.55	9.2	0.0	3.4	2.04	1.45	1.10	.006	481
730	" 8	Clear	.00	.0040	.0026	.0000	.1425	1.70	7 2	0.0	2.8	2.72	1.84	1.52	.010	1,075
732	" 9	.000	.00	0038	.0018	0000	.1350	1 80	8.8	0.0	2.4	2.88	2.13	1.37	006	...
750	" 16	.045	.25	.0060	.0010	0000	.0750	1.18	6.4	0.0	3 2	2.18	1.29	0.89	.040	3,413
752	" 18	.000	.10	.0046	.0010	.0000	...	1.20	6.4	0.0	2.4	1.80	1.09	1.47	.004	271
764	" 21	.023	.10	.0032	0020	.0000	...	1.29	8.0	0 0	2 0	2 64	1.32	1.74	.006	134
771	" 25	.000	.00	.0038	.0022	.0000	...	1.16	8.6	0 0	4.2	2.31	1.40	1.38	006	117
780	" 28	.000	.10	.0030	.0008	.0000	.0375	0.96	8.2	0.0	2.6	1.98	1.20	1 51	.006	145
	Av'gs,	.008	.08	.0038	.0017	.0000	.0862	1.31	7.8	0.0	3.0	2.27	1.41	1.38	.010	741
787	Mar. 4	.000	.00	.0022	.0016	.0000	.0450	1 22	6.8	0.0	1.8	1.80	1.32	1.65	.009	100
800	" 7	.000	.00	.0030	.0016	.0000	.0750	1.30	7.6	0.0	2.4	2.78	1.71	1.72	.004	89
806	" 11	.000	.00	.0028	.0012	.0000	.0525	1.51	7.6	0.0	3.2	3.22	2.10	1.82	.006	109
820	" 14	.006	.00	.0032	.0014	.0000	.0525	1.05	6 4	0.0	2.0	2.06	1.20	0.82	.008	462
825	" 17	.000	.00	0038	.0012	.0000	.0450	1.08	6.4	0.0	2.0	2.21	1.25	1.03	.002	252
835	" 21	.003	.00	.0040	.0016	.0000	.0450	1.56	8.4	0.0	3.2	1.32	0.80	1.37	.008	...
842	" 25	Clear	.00	.0056	.0018	0000	.0525	0.70	6.6	0.0	1.6	1.69	0 48	3.00	.006	118
854	" 28	.000	.00	.0038	.0016	.0000	.0600	0.98	8.4	0.0	2.8	1.68	0.80	1.30	.006	98
	Av'gs,	.001	.00	.0035	.0015	.0000	.0534	1.17	7.3	0.0	2.4	2.09	1.21	1.59	.006	175
863	Apr. 1	.000	.00	.0042	0016	.0000	.0525	0.88	7.6	0.0	1.8	1.32	0 60	1.61	.009	283
876	" 4	.000	.00	.0046	.0014	.0000	.0600	1.00	6.4	0.0	1 2	1.86	1.08	0.44	.006	152
883	" 8	.000	.00	.0042	.0026	.0000	.0450	1.32	8.0	0.0	2.0	1 88	1.46	0.82	.008	91
893	" 11	.000	.00	.0040	.0012	.0000	0525	1.32	8.0	0.0	2.8	2.14	1.65	1.31	.008	124
901	" 15	.000	.00	.0036	.0020	.0000	0600	1.54	9.6	0.0	4.4	2.28	1.84	1.48	.006	145
912	" 18	Clear	.00	.0030	.0020	.0000	0375	1.46	8.4	0.0	2.8	1 80	1.51	1.23	.020	81
921	" 22	.000	.00	.0034	.0018	.0000	.0375	1.00	8.0	0.0	2.0	2.18	1.72	1.52	.004	45
930	" 25	.000	.00	.0044	.0016	.0000	.0375	1.38	8.0	0.0	2 0	2.50	2.05	1 38	.008	570
941	" 29	.000	.00	.0064	.0016	.0000	.0450	1.05	6.4	0.0	2.8	1 38	1.02	1.08	004	124
	Av'gs,	.000	.00	.0042	0018	0000	0475	1.22	7.8	0.0	2.4	1.93	1.44	1.21	008	179

Effluent—Jewell Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
951	May 2	.000	.07	.0032	.0010	.0000	.0225	1.14	7.0	0.0	2 6	1.98	1.60	1.47	.008	32
964	" 5	.000	.00	.0052	.0016	.0000	.0150	1.36	9.2	0.0	2 8	1.90	1.40	1.54	.004	11
974	" 9	.000	.00	.0042	.0014	.0000	.0150	1 02	10.8	0.0	3.8	2.74	1.30	1.79	.006	115
988	" 13	.000	.00	.0038	.0016	.0000	.0150	1.32	7.2	0.0	2.0	2 55	1.78	1.13	.002	50
997	" 16	Clear	.00	.0050	.0020	.0000	.0075	2.40	9.3	0.0	3.2	3.18	1.90	1.20	.004	770
1026	" 23	.000	.00	.0032	.0004	.0000	.0300	1.18	6.8	0.0	2.8	3.20	0.94	1.47	.003	310
1047	" 31	.000	.00	.0032	.0008	.0000	.0450	1.10	6.5	0.0	3.2	2.82	1.53	1.34	.002	23
	Av'gs,	.000	.01	.0040	.0013	.0000	.0214	1.36	8.1	0.0	2.9	2 62	1.49	1.42	.004	185
1071	June 6	.000	.05	.0052	0026	.0000	.0375	2.12	9.0	0.0	2.6	3.88	1 45	2.34	.001	16
1092	" 13	.000	.10	.0044	.0030	.0000	0300	2.20	11.6	0.0	3.4	4.71	2.21	2.51	.002	420
1114	" 20	.012	.00	.0042	.0010	.0000	.0150	1.50	9.4	0.0	3.4	3.56	1.95	1.65	.004	185
1141	" 27	.000	.05	.0062	.0020	.0000	.0450	2.30	11.6	0.0	4.0	3.18	2.02	1.95	.004	300
	Av'gs,	.003	.05	.0050	.0021	.0000	.0319	2.03	10.4	0.0	3.3	3.83	1.91	2.11	.003	230
1167	July 5	Clear	.05	.0056	.0018	.0000	.0600	1.60	12.1	0.0	4.2	3.56	1.94	1.20	.008	610
1192	" 11	.000	.10	.0050	.0016	.0000	.0750	1.98	10.4	0.0	3.0	4.52	2.62	1.65	.002	190
1213	" 18	.000	.05	.0040	.0018	.0000	.0600	3.40	15.8	0.0	5.2	4.80	3.28	2.69	.002	265
1241	" 25	.000	.00	.0042	.0018	.0000	.0450	2.62	16.2	0.0	4.7	5.40	2.10	3.37	.002	67
	Av'gs,	.000	.05	.0047	.0017	.0000	.0600	2.40	13.6	0.0	4.3	4.57	2.48	2.23	.003	285
1260	Aug. 1	.000	.00	.0064	.0022	.0000	.0525	4.12	15.9	0.0	4.8	5.44	3.50	1.85	.002	185
1290	" 8	.000	.05	.0062	.0040	.0000	.0375	2.80	13.0	0.0	4.2	3.80	2.66	1.61	.002	400
1320	" 15	.001	.05	.0060	.0020	.0000	.0600	2.35	10.8	0.0	3.4	3.92	1.76	1.79	.002	115
1350	" 22	.000	.05	.0048	.0024	.0000	.0225	1.48	7.6	0 0	3.0	2.84	0.70	1.95	.002	65
1382	" 29	.000	.05	.0056	.0028	.0000	.0450	1.50	10.8	2.3	3.2	3.35	1.90	1.41	.002	65
	Av'gs,	.000	.04	.0058	.0027	.0000	.0435	2.45	11.6	0.5	3.7	3.87	2.10	1.72	.002	165

Settled Water.

1327	Aug. 15	Slight	.15	...	...	...	...	2.28	13.6	2.8	3.5	3.94	2.00	1.72	.008	2,870
1384	" 29	"	.17	...	...	...	..	1.30	10.0	0.8	3.0	4.28	2.12	0.75	.012	1,400
	Av'gs,	.....	.16	...	...	...	...	1.79	11 8	1.8	3.2	4.11	2.06	1.23	010	2,130

APPLIED WATER—WORMS TILE FILTER.

Samples of the water applied to the "Tile Filter" were collected once a week from the time it was placed in operation until the middle of February, 1898. After this and during the operation of the second test, samples collected from the "Gate Chamber" were considered sufficiently representative of the water applied to the Worms Tile Filter. These samples were collected from the inlet pipe as the water flowed into the Settling Tank.

Applied Water—Worms Tile Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
531	Nov. 27	0.09	.30	.0136	.0014	.0000	.0525	2.86	14.0	3.8	5.8	4.02	3.68	1.36	.070	17,800
548	Dec. 1	0.24	.30	.0128	.0040	.0000	.0750	1.59	11.6	1.6	3.6	2.10	1.89	0.72	.162	23,300
565	" 10	Slight	.25	.0102	0022	.0000	.0675	1 90	11 6	0.4	4.8	3.16	2.01	0.96	.108	25,700
579	" 15	0.38	.30	.0110	.0016	0000	.0825	1.94	15.6	3 2	6.0	2.90	2.42	1.61	.138	15,400
601	" 22	0.40	.30	.0092	.0016	.0000	.0750	1.46	17.6	7.2	5.6	1.98	1.22	1.89	.204	13,050
618	" 30	0.05	.30	.0052	.0018	.0000	.0750	2.10	12.0	0.0	4.8	2.64	1.98	1.51	.080	3,900
	Av'gs,	0.27	.29	.0097	.0022	.0000	.0750	1.80	13 7	2.5	5.0	2.56	1.90	1.34	.138	16,270
	1898.															
633	Jan. 6	0.04	.20	.0064	.0020	.0000	.0675	2.39	13.6	0.0	5.2	2.38	2.05	1.92	.056	3,950
650	" 12	0.57	.30	.0116	.0030	.0000	.1350	2.03	20.0	5.6	6 4	2.02	1.70	1.68	.168	16,125
672	" 20	0.16	.30	0088	.0016	.0000	.0750	1.51	13.6	0.3	6.8	1.89	1.42	1.06	.186	12,300
689	" 26	0.25	.30	0068	.0010	.0000	.1200	1.03	11.6	4.0	3.2	1.22	1.01	0.99	.160	15,000
	Av'gs,	0.25	.27	.0084	.0019	.0000	0994	1.74	14.7	2.5	5.4	1.88	1.54	1.41	.142	11,844
722	Feb. 8	0.04	.30	.0068	.0022	.0000	.1500	1.58	20.2	5.4	8.4	3.18	2.65	1.58	.100	3,550
743	" 15	0.25	.25	.0082	0018	.0000	.0525	1.51	12.8	4.8	3.2	2.39	1.45	0.44	.138	24,150
	Av'gs,	0.14	.27	.0075	.0020	.0000	.1012	1.54	16.5	5.1	5.8	2.78	2.05	1.01	.119	13,850

SETTLED WATER—WORMS TILE FILTER.

Samples of the water, which had been settled by the addition of the chemical and passage through the material in the settling tanks, were collected once a week, from the beginning of the test upon this filter until the first of April, 1898. In June, when the test was renewed, we began to collect these samples once a week and continued until the close of the experiments.

These samples were generally collected during the first test from a quarter-inch petcock, tapped into the three-inch pipe, leading from Settling Tank No. 3 to Filter Tank No. 5. During the second test, they were collected from the surface of the water in the Filter Tank No. 5; with the exception of the sample, dated August 8, 1898, which was collected from the surface of Filter Tank No. 6.

Settled Water—Worms Tile Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
532	Nov. 27	Slight	.30	.0080	.0010	.0000	.1050	4.89	20.4	0.6	8.0	3.76	3.42	1.61	.110	.....
549	Dec. 1	Clear	.10	.0086	.0032	.0000	.0900	4.72	27.2	0.0	10.4	5.98	5.43	1.02	.020	4,200
566	" 10	Slight	.25	.0088	.0016	.0000	.0675	1.99	11.6	0.2	4.8	3.31	2.15	1.03	.152	.....
580	" 15	"	.30	.0068	.0012	0000	.0900	2.22	14.0	...	6.8	3.29	2.84	1.41	.100	11,375
602	" 22	"	.20	.0076	.0012	.0000	.0675	1.31	12.0	0.4	4.4	2.23	1.90	1.72	.156	6,975
619	" 30	V. sl'gt	.30	.0056	.0008	.0000	.0900	2.15	12.8	0.0	5.2	2.76	2.16	1.37	.090	3,225
	Av'gs,	.....	.23	0075	.0016	.0000	.0810	2.48	15.5	0.1	6.3	3.51	2.90	1.31	.104	6,444
	1898.															
634	Jan. 6	Clear	.10	0056	.0020	.0000	.0825	2.16	14.0	0 0	6.0	3.21	2.97	2.13	.040	2,675
652	" 12	Slight	.30	.0056	.0038	.0000	.1800	1.71	16.0	0 6	6.0	2.16	1.85	1.65	.100	5,300
673	" 20	"	.20	.0082	.0014	.0000	.0825	1.57	13.2	0.0	8.0	2.36	1.79	0.89	.162	6,600
690	" 26	V. sl'gt	.25	.0040	.0010	.0000	.1275	1.76	8.8	0.0	3.8	1.48	1.29	0.82	.090	12,100
	Av'gs,	.....	.21	.0058	.0020	.0000	.1181	1.80	13.0	0.1	5.9	2.30	1.97	1.37	.098	6,669

Settled Water—Worms Tile Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as: Albuminoid Ammonia.	Nitrogen as: Free Ammonia	Nitrogen as: Nitrites.	Nitrogen as: Nitrates.	Chlorine.	Residue on Evaporation: Total.	Residue on Evaporation: Suspended.	Residue on Evaporation: Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
706	Feb. 3	V. sl'gt.	.20	.0062	.0014	.0000	.0975	1.62	10.8	0.0	4.8	3.12	2.56	1.27	.070	2,050
723	" 8	Slight	.25	.0052	.0028	.0000	.1425	4.34	22.4	2.4	11.6	3 24	0.90	1.27	.246	1,250
744	" 15	"	.17	.0062	.0018	.0000	.0525	3.08	8.8	0.2	2.2	2.18	1.20	0.55	.046	6,100
762	" 21	"	.10	.0068	.0032	.0000	...	2.38	12.0	0.2	4.4	3 28	2.03	1.07	.074	2,200
781	" 28	V. sl'gt.	.22	.0046	.0010	.0000	.0375	1.48	10.0	0.0	3.2	2.42	1.86	1.48	.016	7,150
	Av'gs,	.....	.19	.0058	.0020	.0000	.0825	2.58	12.8	0.6	5.2	2.85	1.71	1.13	.090	3,750
797	Mar. 7	Slight	.25	.0048	.0012	.0000	.0450	1.65	12.6	0.2	4.0	3.22	2.14	1.51	.022	4,100
817	" 14	V sl'gt	.22	.0024	.0012	0000	.0450	2.80	13.6	0.0	4.8	2.88	1.66	0.55	.020	2,650
832	" 21	Dec'd	.20	.0122	.0014	.0000	.1050	2.00	13.8	0.2	4.0	2.34	1.55	0.37	.074	.....
851	" 28	Slight	.20	.0110	.0014	.0000	.0525	3.51	9.4	0.2	2.4	2.63	1.51	0.89	.008	400
	Av'gs,	.....	.22	.0076	.0013	.0000	.0619	2 49	12.3	0.1	3.8	2.77	1.71	0.83	031	2,383
873	Apr. 4	Slight	.25	.0068	.0012	.0000	.0600	1.96	10.8	0.2	3.6	2.00	1.40	0.96	.048	550
1089	June 13	Clear	.05	.0042	.0010	.0000	.0525	3.70	14.0	0.0	5.0	2.60	2.51	1.47	.002	690
1121	" 20	"	.10	.0098	.0018	0000	.0150	3.60	14 0	0.0	6.0	4.05	1.50	0.75	.008	640
1144	" 27	V. sl'gt.	.05	.0068	.0012	.0000	.0375	4.52	13.9	0.5	4 0	3.60	1.35	0.85	.012	120
	Av'gs,	.....	.07	.0069	.0013	.0000	.0350	3.94	14.0	0.2	5.0	3.42	1.79	1.02	.007	485
1169	July 5	V. sl'gt.	.10	.0044	.0020	.0000	0675	4.55	15 5	0.0	5.6	4.26	1.10	0.17	.016	230
1193	" 11	Clear	.10	.0054	.0018	.0000	.0675	3.79	13.2	0.0	4 0	4.65	2 10	1.13	.016	650
1214	" 18	"	.12	.0052	.0016	.0000	.0525	5.65	23.6	0.0	7.8	4.90	2.07	1.75	.006	680
1242	" 25	"	.05	.0048	.0016	.0000	.0450	5.18	22.2	0.0	8.0	5.85	1.68	2.78	.002	310
	Av'gs,	.....	.09	.0049	.0017	.0000	.0581	4.79	18.6	0.0	6.3	4.91	1.74	1.46	.010	465
1261	Aug. 1	Clear	05	.0060	.0012	0000	.0450	5.70	20 2	0.0	6 0	5.54	2.48	1.34	.004	520
1291	" 8	"	.10	.0060	.0014	.0000	.0450	4.30	17.0	0.0	5 0	4.18	1.88	0.89	.002	710
1321	" 15	"	.20	.0068	0016	0000	.0525	3.00	14.6	0 0	4.6	5.70	3.22	1.82	.006	400
1351	" 22	"	.12	.0044	.0024	.0000	.0300	3.74	15.6	0.0	7.6	4.05	0.64	0.52	.006	88
	Av'gs,	.....	.12	.0058	.0016	.0000	.0431	4.18	16.8	0.0	5.8	4.87	2.05	1.14	.004	430

EFFLUENTS—WORMS TILE FILTER.

Samples of the "Effluents" from the tiles were collected about once a week during both tests. During the first period they were collected from the effluent from Tile A, except upon April 4, 1898, when the effluent from Tile B was sampled; both of these tiles were supplied with chemically treated water. Also from Tiles D and E, which were supplied with untreated water. During the second test all tiles were supplied with chemically treated water, and the samples were collected from the effluent from Tile B; except upon June 13 and August 29, 1898, when the effluents from Tiles A and E, respectively, were sampled. These samples were collected, during the first test, and until July 12, 1898, during the second test, from quarter-inch petcocks on the effluent pipes. After the above date the effluent pipes had a free flow and samples were obtained from the outlets.

Effluent, Tile A—Worms Tile Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
533	Nov. 27	V. sl'gt.	.25	.0078	.0012	.0000	.1125	3.15	17.6	0.2	6.0	3.70	3.40	1.75	.088	35,350
550	Dec. 1	V. sl'gt.	.20	.0110	.0028	.0000	.0900	3.34	18.8	0.0	8.0	4.70	4.09	1.10	.030	11,550
567	" 10	V. "	.20	.0092	.0018	.0000	.0600	2.13	11.2	0.0	4.0	3.46	2.71	1.16	.152	.....
581	" 15	V. "	.10	.0062	.0012	.0000	.0675	2.34	13.2	...	6.8	2.82	2.61	1.47	.088	7,663
603	" 22	V. "	.10	.0064	.0010	.0000	.0975	1.34	11.2	0.0	3.2	2.85	2.20	1.72	.106	3,800
620	" 30	Clear	.10	.0064	.0006	.0000	.0750	2.36	13.2	0.0	4.0	2.88	2.49	1.54	.093	1,262
	Av'gs,	.....	.14	.0078	.0015	.0000	.0780	2.30	13.5	0.0	5.2	3.34	2.82	1.40	.094	6,069
	1898.															
635	Jan. 6	Clear	.00	.0050	.0022	.0000	.0900	2.36	13.2	0.0	4.0	3.30	2.86	2.47	.042	1,237
651	" 12	"	.00	.0062	.0022	.0000	.1800	1.81	18.8	0.0	8.0	2.90	2.32	1.78	.026	1,152
674	" 20	.120	.20	.0030	.0014	.0000	.0975	1.33	12.4	0.0	4.2	2.62	2.00	0.68	.150	2,950
691	" 26	.030	.15	.0032	.0012	.0000	.1125	1.63	8.8	0.0	4.0	1.90	1.36	0.41	.030	4,400
	Av'gs,	.075	.09	.0056	.0017	.0000	.1200	1.78	13.3	0.0	5.0	2.68	2.13	1.33	.062	2,435

Effluent, Tile A—Worms Tile Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
707	Feb. 3	.003	.20	.0048	.0014	.0000	.1050	1.69	9.0	0.0	3.2	2.88	2.45	1.44	.034	1,400
724	" 8	Clear	.00	.0060	.0016	.0000	.1350	4.20	19.6	0.0	5.2	3.19	1.99	1.70	.004	475
745	" 15	"	.05	.0048	.0020	.0000	.0450	3.82	10.6	0.0	4.2	2.31	1.23	0.30	.006	1,000
763	" 21	"	.00	.0040	.0022	.0000	...	2.42	10.4	0.0	3.2	3.07	2.02	1.38	.010	350
782	" 28	.135	.12	.0040	.0018	.0000	.0450	1.10	10.2	0.0	3.8	2.88	2.38	1.17	.050	5,150
	Av'gs,	.069	.07	.0047	.0018	.0000	.0825	2.65	12.0	0.0	3.9	2.87	2.01	1.20	.021	1,675
798	Mar. 7	.010	.17	.0032	.0014	.0000	.0525	1.61	9.2	0.0	2.4	3.84	2.26	1.61	.006	...
818	" 14	.000	.17	.0030	.0014	.0000	.0450	2.30	12.0	0.0	4.8	3.48	2.10	0.34	.002	110
833	" 21	.015	.17	.0060	.0016	.0000	.0600	2.60	13.2	0.0	4.8	3.21	2.30	0.27	.020	...
852	" 28	.034	.17	.0052	.0012	.0000	.0525	2.85	9.2	0.0	2.0	2.82	1.80	0.96	.014	107
	Av'gs,	.015	.17	.0043	.0014	.0000	.0525	2.34	10.9	0.0	3.5	3.34	2.11	0.79	.010	108
874	April 4	V.sl'gt.	.12	.0054	.0012	.0000	.0525	2.28	10.2	0.0	4.4	1.88	1.12	0.48	.010	1,020

Effluents, Tiles D and E—Worms Tile Filter.

(PARTS PER 100,000.)

	1897.															
534	Nov. 27	V.sl'gt.	.25	.0084	.0012	.0000	.1350	3.38	15.2	0.2	6.0	2.88	2.81	1.78	.070	25,175
551	Dec. 1	V.sl'gt.	.20	.0120	.0024	.0000	.0975	1.55	12.0	0.0	6 4	2.64	2.01	0.72	.070	18,900
568	" 10	Clear	.05	.0080	.0026	.0000	.0600	2.19	11.2	0.0	4.2	3.18	2.10	1.13	.050	.....
582	" 15	V.sl'gt.	.05	.0084	.0016	.0000	.0750	2.40	10.8	0.0	3.4	2.23	2.00	1.51	.038	2,963
604	" 22	V. "	.10	.0060	.0015	.0000	.0825	1.27	10.8	0.0	3 6	2.68	1.72	1.51	.082	3,187
621	" 30	Clear	.10	.0068	.0010	.0000	.0750	1.98	11.2	0.0	3.6	2.17	1.86	1.51	.040	1,613
	Av'gs,	.....	.10	.0082	.0018	.0000	.0780	1.88	11.2	0.0	4.2	2.58	1.94	1.28	.056	6,666
	1898.															
636	Jan. 6	Clear	.10	.0046	.0020	.0000	.0825	2.48	12.8	0.0	4.8	2.54	2.20	2.13	.032	1,987
653	" 12	Slight	.20	.0044	.0038	.0000	.1725	1.56	13.6	0.3	4.0	2.28	1.71	1.78	.110	4,900
675	" 20	V.sl'gt.	.10	.0072	.0012	.0000	.0825	1.56	11.2	0.0	6.8	2.40	1.91	0.81	.136	7,450
692	" 26	V. "	.30	.0046	.0012	.0000	.1050	1.14	8.4	0.0	4.0	1.86	1.27	0.65	.060	3,425
	Av'gs,	.....	.17	.0052	.0020	.0000	.1106	1.68	11.5	0.1	4.9	2.27	1.77	1.34	.084	4,440

Effluents, Tiles D and E—Worms Tile Filter.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
708	Feb. 3	V. sl'gt	.20	.0040	.0014	.0000	.1050	1.70	8.8	0.0	3.2	2.07	1.80	1.10	.034	725
725	" 7	Clear	.00	.0064	.0026	.0000	.1200	1.50	11.2	0.0	4.0	3.42	2.20	1.54	.022	300
746	" 16	Slight	.20	.0044	.0020	.0000	.0600	1.40	8.0	0.0	4.0	2.68	1.70	0.48	.050	...
	Av'gs,	.....	.13	0049	.0020	.0000	.0950	1.53	9.3	0.0	3.7	2.72	1.90	1.04	.035	512

Effluent, Tile B—Worms Tile Filter.

(PARTS PER 100,000.)

	1898															
1090	June 13	Clear	.00	.0036	.0008	.0000	.0300	3.62	13.8	0.0	4.4	2.68	3.12	1.58	.001	525
1122	" 20	.010	.00	.0052	.0018	.0000	.0225	3.60	14.8	0.0	5.6	4.15	1.80	0.68	.006	385
1145	" 27	.000	.05	.0058	.0014	.0000	.0375	4.44	15.7	0.0	5.1	3.69	1.50	1.10	.004	285
	Av'gs,	.005	.02	.0049	.0013	.0000	.0300	3.89	14.8	0.0	5.0	3.51	2.14	1.12	.004	400
1170	July 5	Clear	.10	.0036	.0018	.0000	.0825	4.60	15.6	0.0	4 0	4.70	1.50	0.17	.008	770
1194	" 11	.000	.05	.0048	.0012	.0000	.0600	3.50	13.5	0.0	4.9	4.31	2.51	1.47	.012	290
1215	" 18	.000	.10	.0040	.0014	.0000	.0450	5.52	23.4	0.0	8.0	4.94	2.18	1.79	004	185
1243	" 25	.000	.05	.0050	.0016	.0000	.0525	4.30	20.4	0.0	7.0	6.05	2.14	2.24	.002	110
	Av'gs,	.000	.07	.0043	.0015	.0000	.0600	4.48	18.2	0.0	6 0	5.00	2.08	1.42	.006	340
1262	Aug. 1	.000	.05	.0062	.0012	.0000	.0600	5.70	20.0	0.0	6.0	5 93	2.52	1.58	.002	190
1292	" 8	.001	.10	.0060	.0014	.0000	.0450	3.95	16.8	0.0	4.4	4.06	1.79	1.07	.004	190
1322	" 15	.001	.10	.0068	.0020	.0000	.0600	4.30	16.8	0.0	5.2	5.20	2.40	0.92	.002	57
1352	" 22	.000	.10	.0046	.0024	.0000	.0300	3.30	11.7	0.0	4.6	4.00	0.65	0.82	.002	33
1385	" 29	Clear	.05	...	...	...	...	3.00	13.6	0.0	6.2	3.82	1.18	1.23	.004	...
	Av'gs,	.000	.08	.0059	.0017	.0000	.0487	4.05	15.8	0.0	5.3	4.60	1.71	1.12	.003	115

MONONGAHELA RIVER—AT INTAKE OF MONONGAHELA WATER COMPANY.

Samples were collected from the "Monongahela River" at this point, about once a week during the months of June and July, 1897; then twice a week, during the months of August to November, inclusive, 1897; then once a week, until March 14, 1898; and, finally, once in two weeks during the remainder of the work.

The water supply, which is furnished to the South Side Wards, Nos. 24-36, inclusive, by the Monongahela Water Company, is taken from the Monongahela River opposite the foot of Twenty-ninth Street.

In 1888, an intake was placed in the river, about 400 feet from the south shore and connected to the pump well by a 36-inch pipe. The average daily consumption, in this portion of the city, as given by the Water Company for the year 1897, is estimated to be about 12,000,000 gallons per day.

These samples were collected sometimes from the river side of flat boats, moored adjacent to the south bank, a little up stream from the pump station; also, when a small boat could be secured, the samples were collected farther out in the stream over the intake.

Monongahela River—At Intake of Monongahela Water Company.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
7	June 10	.....	...	.0055	.0053	...	...	0.70	12.4	...	2.8	10.50	...	5.36	...	.....
15	" 17	.....	...	.0100	.0160	...	...	0.40	10.8	...	5.2	6.60	...	2.50	...	.....
18	" 21	Mud'y	...	.0270	.0050	...	...	4.00	26.0	11.6	6.8	8.00	...	3.10	...	.....
29	" 30	Dec'd	...	.0120	.0060	.0000	.0740	0.30	12.4	1.2	3.6	4.30	...	3.10	...	.....
	Av'gs,	.....	...	.0136	.0081	.0000	.0740	1.35	15.4	3.2	4.6	7.35	...	3.51	...	.....
31	July 6	.....	...	.0180	.0050	.0000	.1200	0.30	11.6	3.2	3.2	5.00	...	1.50	...	82,970
37	" 12	Dec'd	...	.0136	.0092	.0002	.0306	0.35	9.6	1.2	2.8	4.75	3.00	2.30	. .	.....
46	" 20	Mud'y	...	.0210	.0115	.0002	.0825	0.69	16.8	4.9	3.3	4.93	2.50	2.30	.130	.....
61	" 26	"	...	.0220	.0046	.0001	.0741	0.40	18.5	7.2	3.0	5.20	3.05	2.02	.260	.....
	Av'gs,	.....	...	.0186	.0076	.0001	.0768	0.43	14.1	4.1	3.1	4.97	2.85	2.03	.195	82,970
76	Aug. 2	V. t'd	...	.0160	.0033	.0002	.1334	3.40	10.8	2.7	3.5	4.45	3.60	1.58	.240	3,750
109	" 12	Dec'd	...	.0210	.0063	.0000	.0888	0.72	11.0	1.8	3.6	4.40	2.12	1.65	.165	.....
120	" 16	"	...	.0176	.0039	.0000	.0600	0.45	10.2	2.2	2.8	6.40	2.22	1.72	.160	.....
134	" 20	Slight	...	.0152	.0069	.0000	.0975	0.53	10.8	2.6	4.0	5.61	1.80	2.67	.200	.....
142	" 23	Dec'd	...	.0215	.0126	.0000	.1350	0.61	14.8	2.8	3.0	6.50	1.70	3.06	.270	.....
159	" 26	"	...	.0150	.0138	.0000	.1500	0.94	16.8	4.0	3.6	6.10	1.91	3.92	.310	9,250
167	" 30	Clear	.10	.0148	.0230	.0002	.1200	0.85	15.6	...	4.8	6.68	0.30	6.46	.008	4,125
	Av'gs,	.....	.10	.0173	.0100	.0001	.1121	1.07	12.9	2.3	3.6	5.73	1.95	3.01	.193	5,708

Monongahela River—At Intake of Monongahela Water Company.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
184	Sept. 1	Slight	.35	.0124	.0012	.0000	.0975	0.80	12.0	0.4	2.8	5.45	1.21	4.12	.020	.....
201	" 6	V. sl'gt.	.45	.0102	.0126	.0000	.1125	0.53	12.8	...	4.4	4.63	2.13	3.23	.110	5,300
221	" 9	Slight	.40	.0168	.0142	.0000	.0975	0.95	13.6	...	4.4	6.09	1.21	5.09	.050	27,475
226	" 13	"	.20	.0130	.0162	.0000	.1312	0.62	11.2	...	2.4	6.05	1.41	6.02	.018	7,850
245	" 16	"	.20	.0162	.0118	.0000	.0900	1.25	14.4	...	3.2	6.16	1.08	5.50	.004	14,000
251	" 20	V. sl'gt.	.05	.0126	.0096	.0000	.0450	1.21	15.8	...	4.0	6.59	1.84	4.60	.002	4,300
277	" 23	Slight	.15	.0104	.0092	.0000	.1500	1.39	15.6	...	4.4	6.35	2.14	4.35	.030	175,500
283	" 27	"	.30	.0126	.0161	.0000	.0900	0.82	15.6	...	3.4	5.48	1.66	5.26	.024	268,500
301	" 29	V. sl'gt.	.20	.0128	.0160	.0000	.0675	0.97	19.2	...	6.8	5.35	2.06	6.22	.014	7,700
	Av'gs,	.....	.26	.0130	.0119	.0000	.0979	0.95	14.5	...	4.0	5.79	1.64	4.93	.030	63,828
310	Oct. 4	V. sl'gt.	.20	.0240	.0208	.0000	.0750	1.46	26.0	...	11.6	6.21	1.66	6.43	.026	9,000
331	" 6	Slight	.15	.0340	.0180	.0000	.0825	1.53	23.6	...	8.0	6.70	2.01	7.73	.034	.....
337	" 11	V. sl'gt.	.10	.0460	.0046	.0000	.1500	1.36	26.4	...	8.0	7.51	0.83	8.80	.006	4,550
360	" 13	Slight	.15	.0960	.0024	.0000	.1425	1.92	35.6	...	12.0	6.71	0.38	12.83	.004	12,000
367	" 18	"	.10	.0268	.0180	.0000	.2250	1.59	31.2	...	6.4	...	0.60	15.20	.003	2,800
391	" 20	V. sl'gt.	.10	.0156	.0210	.0000	.1238	1.30	28.8	...	7.2	...	0.70	14.48	.006	2,600
396	" 25	"	.05	.0340	.0260	.0000	.0900	1.38	27.2	...	8.2	6.23	0.58	10.36	.018	51,450
419	" 27	Slight	.10	.0460	.0026	.0000	.1200	1.87	29.2	...	9.8	6.38	0.41	9.15	.020	5,050
	Av'gs,	.....	.12	.0403	.0142	.0000	.1261	1.55	28.5	...	8.9	6.62	0.90	10.62	.015	12,493
426	Nov. 1	Slight	.10	.0142	.0210	.0000	.0525	1.76	18.0	1.2	4.4	6.28	0.85	7.29	.000	3,850
448	" 3	"	.10	.0320	.0280	.0000	.0750	1.93	26.0	2.0	10.8	7.32	1.32	6.88	.024	45,325
458	" 8	.....	.25	.0165	.0240	.0000	.1500	1.61	27.2	0.2	4.8	6.18	0.69	8.11	.126	43,500
478	" 10	Slight	.20	.0180	.0210	.0000	.0225	1.54	23.2	0.4	6.8	6.71	1.39	8.94	.010	.....
486	" 15	.....	.20	.0188	.0110	.0000	.1350	0.97	19.2	5.6	6.4	5.65	1.59	2.71	.158	16,100
499	" 17	Dec'd	.20	.0210	.0046	.0000	.0900	1.31	23.2	6.0	6.8	5.80	0.80	4.00	.300	14,000
506	" 22	.....	.20	.0136	.0044	.0000	.0900	1.05	13.0	0.6	5.4	5.76	1.55	2.33	.060	10,000
536	" 29	Dec'd	.30	.0210	.0020	.0000	.0450	1.58	62.0	33.2	11.2	6.28	3.08	0.89	.310	29,500
	Av'gs,	.....	.19	.0194	.0145	.0000	.0825	1.47	26.5	6.1	7.1	6.25	1.41	5.14	.123	23,182

Monongahela River—At Intake of Monongahela Water Company.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
552	Dec. 6	Mud'y	.40	.0320	.0016	.0000	.2250	0.75	87.2	75.6	11.2	5.18	1.82	1.68	.700	.....
570	" 13	Dec'd	.20	.0140	.0066	.0000	.0750	1.50	18.0	3.6	6.4	3.03	1.54	2.06	.144	11,500
587	" 20	Slight	.20	.0076	.0020	.0000	.1050	1.28	14.0	1.6	4.4	2.43	1.60	1.34	.132	.....
606	" 28	V.sl'gt	.20	.0128	.0020	.0000	.1050	1.73	12.0	0.4	2.0	2.10	0.78	2.26	.112	2,750
	Av'gs,	.....	.25	.0166	.0030	.0000	.1275	1.31	32.8	20.3	6.0	3.18	1.43	1.83	.272	7,125
	1898.															
622	Jan. 3	Slight	.20	.0082	.0020	.0000	.1050	0.91	18.0	6.4	5.6	1.87	1.42	1.78	.140	5,700
644	" 10	"	.25	.0064	.0032	.0000	.1575	1.02	32.0	19.2	7.2	4.22	1.61	2.30	.264	37,250
657	" 17	Dec'd	.20	.0084	.0018	.0000	.1425	0.79	22.0	11.6	5.2	2.14	1.05	1.23	.170	16,700
679	" 24	V.t'd	.20	.0180	.0026	.0000	.1350	0.70	64.0	49.2	10.4	3.14	2.00	1.68	.420	44,100
695	" 31	Slight	.20	.0064	.0056	.0000	.0825	1.14	12.8	0.2	4.2	2.61	0.84	3.30	.038	6,150
	Av'gs,	.....	.21	.0095	.0030	.0000	.1245	0.91	29.8	17.3	6.5	2.80	1.38	2.06	.206	21,980
715	Feb. 7	Slight	.20	.0160	.0022	.0000	.1575	1.12	23.0	0.8	6.6	4.22	0.42	7.50	.020	1,950
734	" 14	Dec'd	.20	.0080	.0028	.0000	.2250	1.52	24.4	12.4	4.8	4.28	1.80	2.20	.016	19,100
754	" 21	"	.20	.0166	.0018	.0000	...	1.00	27.6	16.8	5.6	2.64	1.75	1.13	.380	19,600
772	" 28	"	.20	.0062	.0018	.0000	.0675	0.80	12.8	0.4	2.0	3.10	1.30	3.02	.100	5,450
	Av'gs,	.....	.20	.0117	.0021	.0000	.1500	1.11	21.9	7.6	4.7	3.56	1.32	3.46	.129	11,525
790	Mar. 7	Slight	.20	.0040	.0028	.0000	.0450	1.22	17.4	0.6	7.2	5.80	1.01	4.09	.008	2,000
807	" 14	"	.20	.0052	.0026	.0000	.0450	1.05	13.6	0.4	5.2	5.66	1.01	4.05	.006	5,800
844	" 28	V.t'd	.20	.0148	.0020	.0000	.0375	0.50	30.0	20.4	2.8	3.62	1.10	1.85	.070	25,300
	Av'gs,	.....	.20	.0080	.0025	.0000	.0425	0.92	20.3	7.1	5.1	5.03	1.04	3.33	.028	11,033
864	Apr. 4	Slight	.20	.0038	.0020	.0000	.0450	1.05	12.2	0.2	4.8	2.88	1.10	2.58	.010	9,000
902	" 18	Dec'd	.22	.0120	.0016	.0000	.0450	0.60	13.2	4.8	3.2	1.82	1.20	1.07	.028	8,700
	Av'gs,	.....	.21	.0079	.0018	.0000	.0450	0.82	12.7	2.5	4.0	2.35	1.15	1.82	.019	8,850

Monongahela River—At Intake of Monongahela Water Company.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
942	May 2	Dec'd	.20	.0108	.0016	.0000	.0225	0.80	14.0	4.0	4.0	2.10	1.75	1.13	.020	6,650
989	" 16	"	.35	.0140	.0020	.0000	.0075	1.00	20.4	9.4	3.8	3.70	1.22	2.97	.010	40,900
1048	" 31	Slight	.30	.0128	.0042	.0000	.0525	1.84	15.8	6.5	2.7	3.35	1.42	2.89	.008	25,200
	Av'gs,	.....	.28	.0125	.0026	.0000	.0275	1.21	16.7	6.6	3.5	3.05	1.46	2.33	.013	24,200
1082	June 13	Dec'd	.30	.0122	.0120	.0000	.0225	1.75	15.8	1.0	3.4	2.84	0.74	6.44	.002	8,550
1133	" 27	0.17	.12	.0088	.0072	.0000	.0525	1.10	15.2	2.4	4.0	3.70	1.50	4.05	.006	22,700
	Av'gs,	.....	.21	.0105	.0096	.0000	.0375	1.42	15.5	1.7	3.7	3.27	1.12	5.24	.004	15,600
1184	July 11	Slight	.20	.0142	.0022	.0000	.0675	1.65	19.4	5.0	3.4	5.71	1.74	5.26	.006	.....
1234	" 25	"	.25	.0110	.0060	.0000	.0975	1.20	14.7	2.7	3.9	3.58	0.82	3.13	.006	25,300
	Av'gs,	.....	.22	.0126	.0041	.0000	.0825	1.42	17.0	3.8	3.6	4.64	1.28	4.19	.006	25,300
1307	Aug. 11	0.57	.30	.0190	.0050	.0000	.0375	0.52	29.2	21.6	2.0	1.95	1.62	1.38	.006	34,300

Mineral Analysis.

Sample Collected September 20, 1898.

(PARTS PER 100,000.)

Total Solids	21.80
Loss on Ignition	6.00
Calcium Oxide, (CaO)	3.32
Magnesium Oxide, (MgO)	0.77
Sulphuric Acid, (SO_3)	9.81
Chlorine, (Cl)	1.04
Silica, (SiO_2)	0.47
Iron Oxide, (Fe_2O_3)	0.00

SOUTH SIDE TAP.

Samples of the "Tap Water" upon the South Side were collected, whenever a river sample was obtained, until September 1, 1898. The water is pumped direct from the river to a reservoir upon the hill about one-third of a mile away, of 5,000,000 gallons capacity. The reservoir consists of two basins, one of which is used for settling, and, from the other, the water is distributed over that portion of the city, south of the Monongahela River. The samples were collected from a store upon Carson Street, near 30th Street.

South Side Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation,			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
8	June 10	.....	...	.0120	.0130	...	...	0.90	19.2	...	5.0	10.20	...	5.64	...	...
16	" 17	.....	...	.0100	.0000	...	...	0.35	12.0	...	5.6	8.40	...	3.30	...	...
19	" 21	Mud'y	...	.0340	.0030	.0000	.0370	3.50	52.4	38.8	10.4	6.50	...	2.80	...	...
30	" 30	Dec'd	...	.0120	.0050	.0000	.1110	0.40	15.6	5.2	3.3	4.00	...	3.20	...	...
	Av'gs,	.....	...	.0170	.0052	.0000	.0740	1.29	24.8	11.0	6.1	7.27	...	3.73	...	...
32	July 6	.....	...	.0180	.0030	.0000	.1110	0.40	12.0	2.8	4.8	5.10	...	1.53	...	880
38	" 12	Dec'd	...	.0130	.0062	.0002	.0450	0.65	10.4	1.6	3.2	3.40	4.00	2.65	...	...
47	" 20	Mud'y	...	.0214	.0106	.0002	.0780	0.66	19.9	7.4	3.6	5.31	5.00	2.69	.200	...
62	" 26	"	...	.0230	.0040	.0001	.0815	0.45	21.6	9.1	4.1	6.75	3.09	2.47	.145	...
	Av'gs,	.....	...	.0188	.0059	.0001	.0789	0.54	16.0	5.2	3.9	5.14	4.03	2.33	.172	880
77	Aug. 2	V. t'd	...	.0170	.0023	.0000	.1075	3.25	11.3	2.0	3.8	4.10	3.01	1.49	.260	2,300
110	" 12	Dec'd	...	.0204	.0045	.0000	.0925	0.60	13.0	3.4	4.6	4.52	2.25	1.30	.200	.....
121	" 16	"	...	.0140	.0020	.0000	.0605	0.45	14.6	6.6	3.2	7.71	2.55	2.03	.220	.....
135	" 20	Slight	...	.0174	.0046	.0000	.1050	0.62	13.2	2.2	3.2	6.10	2.72	2.75	.260	.....
143	" 23	Dec'd	...	.0206	.0120	.0000	.1500	0.64	13.0	1.0	5.6	6.60	2.03	3.44	.100	.....
160	" 26	"	...	.0170	.0115	.0000	.1500	1.02	20.6	7.2	4.4	6.50	2.53	4.01	.420	3,650
168	" 30	V. sl'gt	.10	.0144	.0207	.0002	.1275	0.60	18.4	0.2	6.4	7.30	0.80	6.29	.010	1,950
	Av'gs,	.....	.10	.0173	.0082	.0000	.1133	1.03	14.9	3.2	4.5	6.12	2.27	3.04	.210	2,633

South Side Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
186	Sept. 1	Slight	.40	.0120	.0092	.0000	.0825	0.91	14.4	0.4	3.6	5.55	1.38	4.43	.050	5,800
202	" 6	V. sl'gt	.45	.0115	.0104	.0000	.1312	0.44	13.2	...	4.8	5.37	2.21	1.54	.124	1,200
227	" 13	Slight	.30	.0140	.0092	.0000	.1500	0.93	13.6	...	2.0	6.93	1.72	6.29	.052	6,050
246	" 16	"	.20	.0142	.0092	.0000	.1050	1.05	16.4	...	4.4	7.54	1.58	4.78	.036	22,575
252	" 20	V. sl'gt	.05	.0134	.0092	.0000	.0525	1.01	15.6	...	4.4	6.39	1.89	4.98	.004	1,350
278	" 23	Slight	.15	.0136	.0150	.0000	.1575	1.05	15.6	...	5.2	5.32	1.93	4.50	.024	1,300
284	" 27	"	.30	.0108	.0092	.0000	.0975	0.94	17.2	...	5.6	6.30	2.25	5.40	.026	1,475
302	" 29	V. sl'gt	.25	.0136	.0130	.0000	.0750	1.27	18.8	...	5.6	5.51	2.18	6.46	.020	6 300
	Av'gs,	.....	.26	.0129	.0105	.0000	.1064	0.95	15.6	...	4.4	6.11	1.89	4.80	.042	5,756
311	Oct. 4	Slight	.20	.0228	.0160	.0000	.0825	1.11	23.2	...	8.4	5.40	1.21	8.15	.014	1,500
332	" 6	"	.20	.0220	.0160	.0000	.0975	1.34	22.0	...	6.4	6.04	1.18	8.04	.006	2,650
338	" 11	V. sl'gt	.10	.0410	.0042	.0000	.1313	1.29	24.4	...	6.4	6.50	0.62	9.49	.004	350
361	" 13	Slight	.15	.1180	.0026	.0000	.1500	1.52	33.6	...	10.4	6.92	0.45	13.01	.001	100
368	" 18	"	.10	.0240	.0160	.0000	.2160	1.40	30.8	...	6.4	...	0.40	15.03	.001	125
388	" 20	.....	.10	.0128	.0180	.0000	.1575	1.21	29.2	...	6.4	...	0.42	14.55	.006	1,025
397	" 25	V. sl'gt	.05	.0240	.0030	.0000	.0975	1.32	24.4	...	4.8	6.17	0.50	8.63	.006	.....
420	" 27	Slight	.10	.0380	.0030	.0000	.1050	1.69	27.6	...	6.8	6.14	0.35	9.32	.008	7,700
	Av'gs,	.....	.12	.0378	.0098	.0000	.1297	1.36	26.9	...	7.0	6.19	0.64	10.78	.006	1,921
427	Nov. 1	Slight	.10	.0146	.0240	.0000	.0750	1.38	18.4	1.0	5.2	7.21	0.99	7.84	.022	8,500
449	" 3	"	.15	.0248	.0220	.0000	.0975	2.13	24.8	2.0	8.8	6.97	1.14	7.46	.020	13,550
459	" 8	.....	.20	.0148	.0210	.0000	.1575	1.54	24.4	0.1	7.2	6.41	0.88	7.94	.080	9,650
479	" 10	Slight	.20	.0148	.0234	.0000	.0225	1.42	22.8	0.2	7.2	6.53	1.24	8.97	.016	.....
487	" 15	.....	.20	.0140	.0052	.0000	.0225	0.90	16.0	5.2	6.0	5.80	1.60	3.09	.156	8,000
500	" 17	Dec'd	.20	.0128	.0026	.0000	.0750	1.11	26.4	8.4	8.4	6.24	1.14	3.85	.320	5,700
507	" 22	.....	.20	.0120	.0040	.0000	.0900	0.84	13.2	0.5	4.4	5.94	1.67	2.44	.068	8,500
537	" 29	Dec'd	.30	.0188	.0018	.0000	.0750	1.09	42.0	25.8	6.0	4.82	1.92	2.37	.320	13,650
	Av'gs,	.....	.19	.0158	.0130	.0000	.0769	1.30	23.5	5.4	6.6	6.24	1.32	5.49	.125	9,650
553	Dec. 6	.....	.40	.0240	.0018	.0000	.2100	0.80	51.6	39.2	6.0	4.72	1.71	2.33	.430	20,650
571	" 13	Dec'd	.20	.0116	.0036	.0000	.1575	1.26	22.8	10.4	6.4	2.43	1.39	2.30	.204	8,450
588	" 20	Slight	.20	.0080	.0016	.0000	.0975	1.22	21.2	8.4	5.6	3.22	2.25	1.89	.130	.....
607	" 28	"	.20	.0116	.0018	.0000	.1125	1.01	17.2	1.2	5.6	1.98	0.84	3.40	.180	550
	Av'gs,	.....	.25	.0138	.0022	.0000	.1444	1.07	28.2	14.8	5.9	3.09	1.55	2.48	.236	9,883

South Side Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrites.	Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
623	Jan. 3	Slight	.20	.0086	.0016	.0000	.1350	0.99	35.0	24.2	5.4	1.98	1.45	2.51	.460	2,550
645	" 10	"	.25	.0072	.0024	.0000	.0750	0.98	54.0	39.2	10.8	4.12	1.60	2.54	.510	29,050
658	" 17	Dec'd	.30	.0090	.0018	.0000	.1275	1.00	37.6	26.6	8.8	3.40	1.77	2.33	.330	16,200
680	" 24	V. t'd	.20	.0172	.0018	.0000	.1275	0.62	68.0	54.8	9.2	3.08	1.84	2.13	.400	37,100
696	" 31	Slight	.20	.0062	.0020	.0000	.0975	0.73	16.0	5.2	5.0	2.50	0.80	3.19	.235	2,500
	Av'gs,	.....	.23	.0096	.0019	.0000	.1125	0.86	42.1	30.0	7.8	3.02	1.49	2.54	.387	17,480
716	Feb. 7	Slight	.20	.0132	.0028	.0000	.1725	0.82	20.0	1.8	6.4	4.36	0.92	7.22	.248	450
735	" 14	Dec'd	.25	.0084	.0020	.0000	.2400	1.10	20.0	9.6	4.4	4.20	1.75	1.85	.280	8,250
755	" 21	"	.20	.0268	.0020	.0000	...	0.72	91.6	80.4	8.4	2.58	1.75	2.06	.980	21,600
773	" 28	"	.20	.0068	.0016	.0000	.0900	1.51	19.2	7.6	2.8	2.86	0.90	2.72	.300	6,100
	Av'gs,	.....	.21	.0138	.0021	.0000	.1675	1.04	37.7	24.8	5.5	3.50	1.33	3.46	.452	9,100
791	Mar. 7	Slight	.20	.0034	.0024	.0000	.0525	0.78	15.8	1.0	6.0	4.49	0.89	4.44	.006	350
808	" 14	"	.20	.0044	.0022	.0000	.0525	0.84	13.9	0.3	4.8	5.89	1.40	3.78	.012	2,400
845	" 28	V. t'd	.20	.0162	.0016	.0000	.0450	0.94	32.4	22.8	3.2	3.80	1.30	2.09	.070	10,100
	Av'gs,	.....	.20	.0080	.0021	.0000	.0500	0.85	20.7	8.0	4.7	4.73	1.20	3.44	.029	4,283
865	April 4	Dec'd	.20	.0064	.0018	.0000	.0450	0.90	12.7	0.2	5.2	2.92	1.40	2.68	.016	2,300
903	" 18	V. t'd	.25	.0148	.0016	.0000	.0375	0.72	32.4	24.0	2.4	1.98	1.60	1.23	.046	9,450
	Av'gs,	.....	.22	.0106	.0017	.0000	.0412	0.81	22.5	12.1	4.8	2.45	1.50	1.95	.031	5,875
943	May 2	Dec'd	.25	.0106	.0014	.0000	.0150	0.82	17.0	7.0	4.4	2.18	1.76	1.85	.025	1,500
990	" 16	"	.35	.0130	.0018	.0000	.0075	0.76	15.2	6.0	2.6	3.45	2.01	2.24	.015	27,000
1049	" 31	Slight	.30	.0094	.0038	.0000	.0525	0.90	10.9	2.3	2.6	3.48	1.53	2.66	.010	2,100
	Av'gs,	.....	.30	.0110	.0023	.0000	.0250	0.83	14.4	5.1	3.2	3.04	1.77	2.25	.017	10,200
1083	June 13	Dec'd	.32	.0110	.0038	.0000	.0300	0.96	17.3	1.2	4.4	2.85	0.60	5.50	.001	950
1134	" 27	"	.20	.0068	.0068	.0000	.0525	1.06	16.8	3.6	3.8	4.29	1.65	4.44	.008	14,200
	Av'gs,	.....	.26	.0089	.0053	.0000	.0412	1.01	17.0	2.4	4.1	3.57	1.12	4.97	.004	7,550

South Side Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
1185	July 11	Slight	.20	.0130	.0014	.0000	.0825	1.70	19.0	4.4	3.2	5.64	1.72	5.36	.006	.....
1235	" 25	"	.20	.0088	.0048	.0000	.0900	1.00	13.0	0.8	3.6	4.16	1.60	4.51	.008	6,250
	Av'gs,	.....	.20	.0109	.0031	.0000	.0862	1.35	16.0	2.6	3.4	4.90	1.66	4.93	.007	6,250
1308	Aug. 11	Dec'd	.30	.0138	.0042	.0000	.0450	0.68	28.8	21.0	2.2	2.50	1.57	1.85	.008	15,000

ALLEGHENY RIVER AT MONTROSE.

Samples were collected from the "Allegheny River," at the Montrose Pumping Station of the Allegheny City Water Works, four miles above Brilliant, about once a week during the months of June, July and August, 1897. After this time, until December, 1897, the river at Hulton (see page 285) was taken as fairly representative of the river at Montrose. It was then found that the analyses of these river samples differed but very little from those collected at Brilliant and, throughout the remainder of the work, the samples collected at the latter place were taken as fairly representing the conditions at Montrose, Hulton and Wildwood.

A portion of the water supply for the city of Allegheny has been obtained from the river at Montrose since April, 1897. At first about one-third of the water used was pumped from here and the remainder from the city pumping station near Herr's Island. At the close of our work, almost all of the water was pumped from Montrose, being about 30,000,000 gallons per day; occasionally, however, about 5,000,000 was pumped from the lower station.

The water is obtained from a crib in the river, which is connected by four 36-inch pipes with the pump well. This crib is about 2,500 feet long, 32 feet wide, and 7 feet deep, and was built of 6-inch x 8-inch hemlock timber, laid flat. The timbers are separated by blocks, four inches thick, spaced about three feet apart. The crib is tightly planked over on top with three-inch planks, but the sides, ends, and bottom are open. In placing the crib, an excavation, somewhat larger than the area of the structure, was made and the crib floated over and sunk into place

by loading with large stones. Stones were then placed around the sides and upon the top; and covered with layers of coarse gravel, with sand upon top. The average depth of gravel and sand on the crib is five feet. The depth of water over the crib at low water is 16 feet at the upper end and 10 feet at the lower end. The center line of the crib is 300 feet from the river wall of the pumping station. Upon two occasions it was thought that some of the sand and gravel had been washed away and a considerable amount of new material was dumped in place. The samples were collected over the crib from the ferry boat which crosses the river between Montrose and Verona.

Allegheny River at Montrose.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
12	June 15	.....	...	.0160	.0000	...	...	1.50	9.8	...	4.8	10.20	...	0.99	...	.....
24	" 28	.....	...	.0180	.0000	.0000	.0630	1.80	11.6	...	5.6	4.80	...	1.42	.000	.....
	Av'gs,	.....	...	.0170	.0000	.0000	.0630	1.65	10.7	...	5.2	7.50	...	1.20	.000	.....
39	July 12	.....	...	.0170	.0002	.0002	.0034	2.15	12.4	0.4	6.0	4.35	8.00	1.38	.002	.....
48	" 20	Mud'y	...	.0428	.0025	.0001	.0285	1.30	42.7	28.4	7.6	5.22	8.00	1.40	.240	.....
67	" 28	"	...	.0310	.0034	.0000	.1036	0.91	32.5	23.6	4.9	4.50	4.78	1.14	.420	9,150
	Av'gs,	.....	...	.0303	.0020	.0001	.0452	1.45	29.2	17.5	6.2	4.69	6.93	1.31	.221	9,150
96	Aug. 9	Slight	..	.0197	.0011	.0000	.0888	1.20	10.0	0.6	4.1	5.50	6.19	1.18	.065	700
118	" 16	V. t'd	...	.0340	.0060	.0000	.0750	4.70	20.0	3.2	7.0	10.00	4.28	1.10	.100	2,225
146	" 23	Slight	...	.0190	.0020	.0000	.0750	1.24	8.2	0.6	3.4	5.19	3.78	0.86	.120	3,050
179	" 30	Dec'd	.45	.0190	.0028	.0000	.1200	1.86	11.2	0.2	5.2	5.50	4.36	1.51	.080	4,550
	Av'gs,	.....	.45	.0229	.0030	.0000	.0897	2.25	12.3	1.1	4.9	6.55	4.65	1.16	.091	2,631
218	Sept. 7	Slight	.25	.0140	.0024	.0000	.0600	2.09	11.2	...	4.6	5.26	5.15	0.86	.026	15,050
266	" 22	V. slg't.	.30	.0122	.0014	.0000	.0712	1.08	15.6	...	6.0	5.81	5.52	1.64	.044	2,250
	Av'gs,	.....	.27	.0131	.0019	.0000	.0656	1.58	13.4	...	5.3	5.53	5.33	1.25	.035	8,650

EFFLUENT—MONTROSE CRIB.

Samples of the water which had passed through this crib into the pump well were collected once a week, from the beginning to December 1, 1897; after which they were collected once in two weeks. These samples were collected from the lower floor in the pumping station, by lowering the bottle into the pump well.

Effluent—Montrose Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
13	June 15	.....	...	.0110	.0000	...	...	1.50	13.6	...	7.2	10.40	...	1.09	...	.....
25	" 28	.....	...	.0180	.0000	.0000	.0550	1.60	11.2	...	6.0	4.70	...	1.55	.000	.....
	Av'gs,	.....	...	.0145	.0000	.0000	.0550	1.55	12.4	...	6.6	7.50	...	1.32	.000	.....
40	July 12	Slight	...	.0201	.0048	.0003	.0015	2.07	12.4	0.1	6.0	5.93	...	1.42	.008	.....
49	" 20	Mud'y	...	.0392	.0030	.0001	.0405	1.37	34.9	22.2	7.2	5.03	8.00	1.24	.280	.....
68	" 28	"	..	.0315	.0046	.0000	.1165	1.02	26.2	16.6	4.8	4.45	4.59	1.41	.400	9,200
	Av'gs,	.....	...	.0303	.0041	.0001	.0528	1.49	24.5	13.0	6.0	5.14	6.29	1.36	.229	9,200
78	Aug. 2	Dec'd	...	.0220	.0020	.0001	.1112	1.22	11.1	1.4	4.2	4.39	5.15	0.87	.140	2,400
97	" 9	Slight	...	.0250	.0027	.0000	.0666	1.40	10.2	...	4.2	5.54	6.64	1.31	.070	725
119	" 16	Dec'd	...	.0174	.0050	.0000	.0375	1.50	11.2	1.2	4.2	7.80	4.50	1.17	.140	15,050
147	" 23	Slight	...	.0195	.0020	.0000	.0525	1.30	9.6	0.4	2.4	5.59	3.82	0.92	.160	2,575
180	" 30	"	.40	.0175	.0018	.0000	.0750	1.75	10.2	...	5.0	5.70	4.37	1.27	.050	10,050
	Av'gs,	.....	.40	.0203	.0027	.0000	.0686	1.43	10.5	0.6	4.0	5.80	4.90	1.11	.112	6,160
206	Sept. 7	Slight	.35	.0176	.0032	.0000	.0675	2.15	12.0	...	4.0	4.88	5.01	1.41	.030	17,500
236	" 14	"	.30	.0124	.0018	.0000	.0375	2.08	13.2	...	5.2	5.80	5.90	1.51	.020	1,675
268	" 22	"	.30	.0180	.0034	.0000	.0300	2.96	15.2	...	4.0	5.84	5.92	1.72	.052	2,425
298	" 28	V.sl'gt.	.25	.0120	.0014	.0000	.0825	1.99	13.2	...	6.0	3.68	3.56	2.88	.062	4,575
	Av'gs,	.....	.30	.0150	.0024	.0000	.0544	2.29	13.4	...	4.8	5.05	5.10	1.88	.041	6,544

Effluent—Montrose Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
318	Oct. 5	Slight	.40	.0166	.0018	.0000	.0750	3.25	16.8	...	7.2	4.97	4.56	2.37	.058	3,050
353	" 12	V. sl'gt	.25	.0146	.0018	.0000	.0825	3.04	16.0	..	6.4	5.23	4.77	1.85	.036	42,000
390	" 19	"	.20	.0110	.0010	.0000	.0600	2.84	16.4	...	6.4	5.28	5.06	2.58	.042	173,000
413	" 26	"	.20	.0090	.0012	.0000	.0375	2.88	19.2	...	6.4	5.40	5.22	2.40	.048	171,000
	Av'gs,	.....	.26	.0128	.0014	.0000	.0637	3.00	17.1	...	6.6	5.22	4.90	2.30	.046	97,262
437	Nov. 2	V. sl'gt	.15	.0060	.0020	.0000	.0450	4.40	20.0	0.2	7.6	5.39	5.30	2.57	.048	66,500
473	" 9	Slight	.25	.0120	.0016	.0000	.0450	4.05	17.6	0.6	5.6	5.38	5.12	2.95	.098	17,900
494	" 16	Dec'd	.40	.0240	.0032	.0000	.0675	2.86	25.2	7.6	9.6	4.72	4.45	1.44	.180	19,500
524	" 23	Slight	.40	.0122	.0012	.0000	.1350	1.88	12.8	0.0	5.8	2.96	2.65	1.13	.100	13,100
	Av'gs,	.....	.30	.0135	.0020	.0000	.0731	3.30	18.9	2.1	7.1	4.61	4.38	2.02	.106	29,250
561	Dec. 7	Slight	.30	.0096	.0016	.0000	.0900	2.90	17.2	5.2	6.4	3.22	2.36	0.86	.232	27,000
600	" 21	"	.30	.0084	.0018	.0000	.1050	6.44	28.8	0.4	11.6	2.68	2.13	0.99	.078	.....
	Av'gs,	.....	30	.0090	.0017	.0000	.0975	4.67	23.0	2 8	9.0	2.95	2.24	0.92	.155	27,000
	1898.															
629	Jan. 4	V. sl'gt	.30	.0084	.0040	.0000	.0525	6.47	40.0	0.0	12.8	5.19	4.43	1.82	.052	44,800
671	" 18	Slight	.30	.0096	.0050	.0000	.0750	17.41	68.0	0.4	19.2	10.50	2.64	0.92	.080	16,000
	Av'gs,	.....	.30	.0090	.0045	.0000	.0637	11.94	54.0	0.2	16.0	7.84	3.53	1.37	.066	30,400
749	Feb. 16	Slight	.35	.0058	.0028	.0000	.1125	23.10	76.2	0.2	10.0	4.22	3.18	0.96	.086	13,900
784	Mar. 1	V. sl'gt	.25	.0072	.0030	.0000	.0525	16.92	49.6	0.2	5.2	4.22	3.32	1.15	.028	8,350
823	" 15	"	.25	.0048	.0022	.0000	.0450	38.90	95.2	0.4	20.0	7.32	4.95	0.82	.030	7,650
856	" 29	Slight	.25	.0108	.0020	.0000	.0525	21.42	55.6	0.8	10.6	5.12	4.04	1.06	.022	7,900
	Av'gs,	.....	.25	.0076	.0024	.0000	.0500	25.75	66.8	0.5	11.9	5.55	4.10	1.01	.027	7,967

Effluent—Montrose Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
896	Apr. 12	Slight	.25	.0062	.0020	.0000	.0750	8.80	20.8	0.4	4.0	3.80	3.35	1.05	.046	4,050
934	" 26	"	.22	.0078	.0028	.0000	.0600	15.30	52.8	0.8	12.0	4.48	4.12	0.34	.032	11,650
	Av'gs,	.....	.23	.0070	.0024	.0000	.0675	12.05	36.8	0.6	8.0	4.14	3.73	0.69	.039	7,850
982	May 10	Slight	.27	.0088	.0052	.0000	.0150	11.85	40.4	0.2	10.4	9.90	4.20	1.13	.028	4,400
1033	" 24	"	.35	.0110	.0032	.0000	.0450	10.15	38.6	0.4	9.2	10.70	4.10	0.61	.012	10,800
	Av'gs,	.....	.31	.0099	.0042	.0000	.0300	11.00	39.5	0.3	9.8	10.30	4.15	0.87	.020	7,600
1077	June 7	Dec'd	.27	.0072	.0042	.0000	.0225	5.30	19.5	0.7	6.0	5.88	3.52	1.00	.002	69,300
1126	" 21	"	.32	.0180	.0010	.0000	.0225	5.00	38.8	19.6	6.8	4.66	3.36	1.00	.026	16,700
	Av'gs,	.....	.29	.0126	.0026	.0000	.0225	5.15	29.1	10.1	6.4	5.27	3.44	1.00	.014	43,000
1176	July 6	V. sl'gt.	.27	.0110	.0018	.0000	.1200	2.22	9.8	0.2	4.0	3.40	3.36	0.55	.024	10,300
1224	" 19	Slight	.25	.0078	.0016	.0000	.0750	2.60	13.2	0.2	3.8	6.21	4.00	2.06	.014	28,300
	Av'gs,	.....	.26	.0094	.0017	.0000	.0975	2.41	11.5	0.2	3.9	4.80	3.68	1.30	.019	19,300
1278	Aug. 2	Slight	.27	.0074	.0030	.0000	.0600	5.28	31.0	9.2	7.4	7.38	5.52	1.54	.016	20,100
1329	" 16	"	.30	.0148	.0020	.0000	.0525	3.08	14.6	0.8	4.6	5.60	3.70	1.38	.010	22,000
	Av'gs,	.....	.28	.0111	.0025	.0000	.0562	4.18	22.8	5.0	6.0	6.49	4.61	1.46	.013	21,000

ALLEGHENY CITY TAP.

Samples were collected of the "Tap Water" in the city of Allegheny once a week from the beginning of the work until December 1, 1897, and then once in two weeks for the remaining time.

The water from Montrose is pumped to a reservoir in the city, of 7,000,000 gallons capacity, and there mingles with the water pumped from the city station. From this reservoir the water is distributed over

the city, but a change is now being made so that water from Montrose may be distributed direct to the city without going to the reservoir.

These samples were collected in a store upon Federal Street, near the railroad station.

Allegheny City Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as.				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
26	June 30	.....	...	.0140	.0000	.0000	.0180	1.80	12.8	...	6.4	6.00	...	1.87	.000	.....
45	July 13	Dec'd	...	.0145	.0013	.0002	.0030	4.35	15.6	0.2	6.8	4.25	8.50	1.75	.006	2,880
50	" 20	Mud'y	...	.0372	.0018	.0001	.0360	1.55	42.5	28.0	7.0	5.15	7.50	1.74	.360	.....
70	" 28	"	...	.0350	.0013	.0000	.1230	0.95	25.6	15.7	4.2	5.03	5.43	1.03	.260	7,800
	Av'ge,	.....	...	.0289	.0015	.0001	.0540	2.28	27.9	14.6	6.0	4.81	7.14	1.51	.209	5,340
79	Aug. 2	Slight	...	.0180	.0013	.0000	.1408	1.28	12.2	3.1	3.8	4.36	5.10	0.62	.155	1,050
132	" 20	"	...	.0196	.0018	.0000	.0600	1.29	10.8	2.8	4.8	5.75	3.90	0.27	.160	.....
178	" 31	Dec'd	.10	.0184	.0028	.0000	.0675	1.81	16.8	5.6	5.6	5.84	4.58	1.34	.270	2,425
	Av'ge,	.....	.10	.0187	.0020	.0000	.0894	1.46	13.3	3.8	4.7	5.32	4.53	0.74	.195	1,737
217	Sept. 7	Slight	.40	.0158	.0018	.0000	.0450	1.90	11.6	...	2.8	5.22	4.89	1.20	.044	8,170
230	" 13	"	.40	.0140	.0018	.0000	.0375	2.49	14.0	...	5.0	7.95	5.76	0.79	.044	12,700
260	" 21	"	.25	.0102	.0012	.0000	.0450	3.22	17.6	...	7.6	7.15	5.51	1.58	.056	1,900
282	" 27	"	.35	.0112	.0012	.0000	.0375	3.12	17.2	...	6.0	5.46	4.89	3.30	.036	6,475
	Av'ge,	.....	.35	.0128	.0015	.0000	.0412	2.68	15.1	...	5.3	6.44	5.26	1.72	.045	7,311
309	Oct. 4	Slight	.40	.0152	.0008	.0000	.0675	2.86	17.2	...	7.2	5.60	5.34	3.09	.094	13,400
342	" 11	V. sl'gt	.30	.0148	.0020	.0000	.1350	3.32	15.2	...	5.2	5.01	4.74	2.16	.070	51,150
366	" 18	V. "	.40	.0143	.0028	.0000	.0675	3.61	18.8	...	6.4	5.10	4.90	2.82	.052	135,000
395	" 25	V. "	.20	.0120	.0038	.0000	.0450	3.38	18.8	...	7.6	5.60	5.30	2.64	.036	154,500
	Av'ge,	.....	.32	.0141	.0023	.0000	.0787	3.29	17.5	...	6.6	5.33	5.07	2.68	.063	88,512

Allegheny City Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
425	Nov. 1	Slight	.20	.0120	.0048	.0000	.0450	3.70	21.2	0.5	11.2	5.70	5.45	2.51	.078	198,000
457	" 8	"	.30	.0110	.0016	.0000	.0900	3.85	24.2	1.8	9.6	5.28	4.99	3.88	.086	44,300
485	" 15	Dec'd	.40	.0220	.0048	.0000	.0150	2.69	25.6	6.4	8.8	4.90	4.46	2.47	.200	6,900
505	" 22	"	.40	.0148	.0010	.0000	.0675	1.50	15.2	2.0	3.6	3.90	3.20	1.16	.136	1,381
535	" 29	"	.40	.0340	.0014	.0000	.0825	3.06	70.4	52.4	15.2	4.13	3.39	1.27	.510	36,050
	Av'gs,	.....	.34	.0188	.0027	.0000	.0600	2.96	31.3	12.6	9.7	4.78	4.30	2.26	.202	57,326
569	Dec. 13	Slight	.30	.0120	.0034	.0000	.1425	3.02	18.4	0.4	8.4	3.50	3.14	1.20	.088	12,600
605	" 28	"	.30	.0140	.0018	.0000	.0825	5.31	28.4	0.6	14.0	5.60	2.51	1.65	.122	8,050
	Av'gs,	.....	.30	.0130	.0026	.0000	.1125	4.16	23.4	0.5	11.2	4.55	2.82	1.42	.105	10,325
	1898.															
643	Jan. 10	Slight	.30	.0056	.0020	.0000	.1275	3.34	34.0	15.6	10.8	3.24	2.92	1.61	.260	18,700
678	" 24	V. t'd	.25	.0108	.0022	.0000	.0300	8.72	57.8	25.0	28.8	3.20	2.91	0.86	.320	27,200
	Av'gs,	.....	.27	.0082	.0021	.0000	.0787	6.03	45.9	20.3	19.8	3.22	2.91	1.23	.290	22,950
714	Feb. 7	Slight	.25	.0128	.0040	.0000	.1500	7.52	34.0	0.4	8.0	3.48	3.13	1.30	.180	4,300
753	" 21	"	.22	.0140	.0022	.0000	...	8.72	36.4	2.4	11.6	4.26	3.22	1.75	.112	3,550
	Av'gs,	.....	.23	.0134	.0031	.0000	.1500	8.12	35.2	1.4	9.8	3.87	3.17	1.52	.146	3,925
789	Mar. 7	Slight	.25	.0042	.0014	.0000	.0525	3.87	18.0	0.4	6.0	4.17	3.30	1.38	.028	15,550
846	" 28	V. t'd	.25	.0284	.0030	.0000	.0375	4.22	50.0	38.8	2.8	3.28	2.16	0.96	.062	6,850
	Av'gs,	.....	.25	.0163	.0022	.0000	.0450	4.04	34.0	19.6	4.4	3.72	2.73	1.17	.045	11,200
884	Apr. 11	Slight	.22	.0084	.0018	.0000	.0600	5.42	19.8	0.2	7.2	3.28	2.85	1.24	.046	3,250
931	" 26	Dec'd	.25	.0074	.0018	.0000	.0225	7.13	24.8	0.4	8.4	4.22	3.98	0.71	.045	5,700
	Av'gs,	.....	.23	.0079	.0018	.0000	.0412	6.27	22.3	0.3	7.8	3.75	3.41	0.97	.045	4,475

Allegheny City Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
967	May 9	Dec'd	.30	.0180	.0016	.0000	.0150	5.96	35.6	18.0	13.6	7.92	3.35	0.96	.152	10,000
1019	" 23	Mud'y	.60	.0380	.0008	.0000	.0300	7.22	81.0	55.8	8.0	7.10	3.48	0.89	.051	6,850
	Av'gs,	.....	.45	.0280	.0012	.0000	.0225	6.59	58.3	36.9	10.8	7.51	3.41	0.92	.101	8,400
1062	June 5	Slight	.30	.0050	.0020	.0000	.0225	3.52	12.8	1.2	3.8	5.20	3.40	0.75	.009	1,950
1108	" 20	Dec'd	.35	.0122	.0010	.0000	.0225	4.97	65.6	45.2	7.8	5.00	3.70	1.07	.030	.....
	Av'gs,	.....	.32	.0086	.0015	.0000	.0225	4.24	39.2	23.2	5.8	5.10	3.55	0.91	.019	1,950
1160	July 5	Slight	.30	.0120	.0024	.0000	.0675	4.30	18.4	2.9	5.2	4.84	3.32	0.22	.026	1,000
1206	" 18	"	.30	.0072	.0018	.0000	.0525	4.53	19.8	0.2	7.4	7.10	4.10	1.68	.030	12,600
	Av'gs,	.....	.30	.0096	.0021	.0000	.0600	4.41	19.1	1.5	6.3	5.97	3.71	0.95	.028	6,800
1253	Aug. 1	Slight	.25	.0116	.0018	.0000	.0600	5.26	30.2	11.0	5.8	6.80	5.03	1.41	.026	20,600
1313	" 15	"	.30	.0100	.0016	.0000	.0525	2.78	15.6	4.8	3.4	4.00	2.90	1.16	.030	6,500
	Av'gs,	.....	.27	.0108	.0017	.0000	.0562	4.02	22.9	7.9	4.6	5.40	3.96	1.28	.028	13,500

ALLEGHENY RIVER AT HULTON.

Samples were collected from the "Allegheny River at Hulton," about six miles above Brilliant, once a week during the months of August to November, inclusive, 1897. After this time the samples collected from the river at Brilliant may be taken as fairly representing the river at Hulton.

The water supply, furnished by the Suburban Water Company to Oakmont and Verona, is derived from the river at this point. The pumpage is given as about 300,000 gallons daily. The water is obtained from a crib situated in the river and about 260 feet from the pumping station, to which it is connected by a 12-inch pipe. The crib was built in 1894, of 2-inch x 4-inch hemlock, in a crate style something like the Montrose

Crib, but is open on top. It is 96 feet long, 16 feet wide, and 4 feet deep, It is covered with large stones, gravel and sand, about 4½ feet deep. The average depth of water at low water is about seven feet. The samples were collected from the bank in the current and near the station.

Allegheny River at Hulton.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
93	Aug. 9	Slight	....	.0215	.0021	.0000	.0815	1.17	10.1	0.7	4.1	5.58	5.89	1.10	.070	650
115	" 16	Dec'd	....	.0208	0021	.0000	0900	1.10	11.4	2.8	2.8	7.90	5.65	0.99	.100	525
144	" 23	Slight	....	.0185	0016	.0000	.0638	1.10	9.0	2.4	4.4	5.02	3 73	0.82	.070	1,150
	Av'gs,	.....	....	.0203	.0019	.0000	.0784	1.12	10.2	2.0	3.8	6.17	5.09	0.97	.080	775
233	Sept. 14	Slight	.20	.0133	.0024	.0000	.0450	1.97	14.0	...	6.4	6.42	5.49	1.54	.040	250
293	" 28	"	.25	.0174	.0028	.0000	.0900	2.01	17.2	...	7.2	3.90	3.79	2.88	.062	3,300
	Av'gs,	.....	.22	.0153	.0026	.0000	.0675	1.99	15.6	...	6.8	5.16	4.64	2 21	051	1,775
316	Oct. 5	V. sl'gt.	.30	.0162	.0012	.0000	.0775	3.12	17.6	...	8.4	5.01	4.75	2.23	.068	12,250
351	" 12	Slight	.30	.0108	.0010	.0000	.0600	2.84	15.0	...	5.8	5.10	4.70	1.96	.044	5,700
378	" 19	V. "	30	.0105	0012	.0000	.0600	2.79	17.6	...	7.2	5.80	5.25	2.61	.050	90,000
410	" 26	V. "	.30	.0078	.0014	.0000	.0375	3.75	23.2	...	12.2	5.39	5.20	2.54	066	87,000
	Av'gs,	.....	.30	.0113	.0012	.0000	.0587	3.12	18.3	...	8.4	5.32	4.97	2.33	.057	48,737
439	Nov. 2	Clear	.20	.0060	.0012	.0000	.0450	3.51	17.8	0.0	6.4	5.28	5.11	2 50	.052	32,000
470	" 9	Slight	.20	.0122	.0016	.0000	.0525	3.45	19.6	0.4	5.2	4.80	4.65	2.85	066	7,800
491	" 16	Dec'd	.35	0266	.0054	.0000	.1200	1 85	26.0	10.8	6 0	3.31	2.95	1.89	.288	15,010
517	" 23	Slight	.30	.0140	.0010	0000	.0675	1.44	12.2	0.6	5.2	2.76	2.31	1 20	.110	15,700
	Av'gs,	.....	.26	.0147	.0023	.0000	.0712	2.56	18.9	2.9	5.7	4.04	3.75	2.11	.129	17,627

EFFLUENT—HULTON CRIB.

Samples were collected of the water which had passed through the crib, once a week during the months of August to November, inclusive, 1897; then once in two weeks until May 1, 1898, and again once a week, until the close of the experiments. These samples were collected from a small petcock on the steam pump.

Effluent—Hulton Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
94	Aug. 9	Clear	...	.0108	.0009	.0000	.0592	3.53	15.6	...	4.0	7.22	10.16	1.22	.030	135
116	" 16	Slight	...	.0130	.0014	.0000	.0605	2.40	13.0	...	5.4	8.85	6.36	1.00	.090	1,071
145	" 23	V.Sl'gt	...	.0110	.0018	.0000	.0525	4.48	15.2	...	3.2	7.28	7.27	0.55	.030	135
175	" 30	V. "	.35	.0140	.0010	.0000	.0525	3.02	13.6	...	6.0	6.93	5.42	1.10	.040	1,953
	Av'gs,	.....	.35	.0122	.0013	.0000	.0562	3.36	14.3	...	4.6	7.57	7.30	0.97	.047	823
234	Sept. 14	V.Sl'gt	.20	.0094	.0016	.0000	.0450	2.97	14.8	...	5.2	7.22	6.64	1.31	.032	68
294	" 28	Slight	.20	.0102	.0014	.0000	.0750	3.90	18.0	...	6.4	5.97	5.77	2.16	.058	2,250
	Av'gs,	.....	.20	.0098	.0015	.0000	.0600	3.43	16.4	...	5.8	6.59	6.20	1.73	.045	1,159
317	Oct. 5	Clear	.20	.0096	.0014	.0000	.0825	3.68	17.2	...	6.4	5.70	5.22	1.85	.046	6,336
352	" 12	V.Slg't	.20	.0118	.0005	.0000	.0825	3.97	16.4	...	6.0	6.21	5.66	1.20	.030	3,846
379	" 19	V. "	.20	.0090	.0010	.0000	.0675	3.80	19.6	...	6.8	6.13	5.80	2.30	.047	34,560
411	" 26	V. "	.20	.0080	.0016	.0000	.0525	5.14	29.2	...	10.4	6.42	6.04	2.20	.046	39,825
	Av'gs,	.....	.20	.0096	.0011	.0000	.0712	4.15	20.6	...	7.4	6.11	5.68	1.89	.042	21,142
440	Nov. 2	V.Sl'gt	.15	.0084	.0014	.0000	.0450	5.34	20.4	0.1	7.6	6.72	6.15	2.23	.036	27,000
471	" 9	Clear	.15	.0088	.0018	.0000	.0525	6.31	22.0	0.0	6.4	6.88	6.65	1.99	.030	2,100
492	" 16	"	.10	.0160	.0058	.0000	.0825	6.22	24.0	0.0	8.0	7.14	6.83	0.89	.016	100
518	" 23	"	.20	.0068	.0014	.0000	.0450	6.07	22.0	0.0	8.4	7.16	6.76	0.99	.018	167
	Av'gs,	.....	.15	.0100	.0026	.0000	.0562	5.98	22.1	0.0	7.6	6.97	6.60	1.52	.025	7,342

Effluent—Halton Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
563	Dec. 7	Clear	.10	.0048	.0016	.0000	.0075	6.81	21.2	0.0	8.0	9.24	8.85	0.96	.004	48
598	" 21	"	.20	.0048	.0010	.0000	.0825	5.65	18.8	0.0	5.2	7.82	6.81	1.03	.012	...
	Av'gs,	.....	.15	.0048	.0013	.0000	.0900	6.23	20.0	0.0	6.6	8.53	7.83	0.99	.008	48
	1898.															
632	Jan. 4	Clear	.10	.0044	.0018	.0000	.0750	2.27	21.2	0.0	5.6	6.90	6.98	1.41	.008	93
669	" 18	"	.10	.0040	.0028	.0000	.0825	5.04	17.6	0.0	7.2	6.10	5.29	0.72	.036	952
	Av'gs,	.....	.10	.0042	.0023	.0000	.0787	3.65	19.4	0.0	6.4	6.50	6.13	1.06	.022	522
704	Feb. 1	Clear	.15	.0028	.0020	.0000	.0750	5.18	14.4	0.0	3.6	5.86	5.52	0.65	.014	333
747	" 16	"	.10	.0040	.0016	.0000	.0825	4.45	16.8	0.0	5.2	5.84	4.85	0.68	.010	861
	Av'gs,	.....	.12	.0034	.0018	.0000	.0787	4.81	15.6	0.0	4.4	5.85	5.18	0.66	.012	597
783	Mar. 1	Clear	.12	.0038	.0028	.0000	.0450	5.00	17.6	0.0	4.8	7.19	6.18	1.17	.010	195
821	" 15	"	.17	.0036	.0012	.0000	.0375	4.30	13.2	0.0	3.2	6.32	5.40	0.34	.010	143
857	" 30	"	.12	.0030	.0020	.0000	.0450	3.95	14.0	0.0	4.0	5.16	4.41	0.61	.036	504
	Av'gs,	.....	.14	.0035	.0020	.0000	.0425	4.42	14.9	0.0	4.0	6.22	5.33	0.71	.019	281
894	April 12	Clear	.12	.0042	.0018	.0000	.0600	4.32	16.0	0.0	4.8	5.62	4.90	0.60	.010	135
932	" 26	"	.12	.0060	.0014	.0000	.0450	2.55	10.4	0.0	3.6	4.28	3.97	0.44	.012	480
	Av'gs,	.....	.12	.0051	.0016	.0000	.0525	3.43	13.2	0.0	4.2	4.95	4.43	0.52	.011	307
958	May 3	Clear	.10	.0038	.0022	.0000	.0075	2.30	9.2	0.0	2.0	3.80	3.31	0.30	.010	910
978	" 10	V. sl'gt	.20	.0064	.0016	.0000	.0225	3.10	11.8	0.0	2.6	4.42	3.68	0.58	.018	1,130
1000	" 17	Clear	.10	.0036	.0018	.0000	.0150	3.90	12.8	0.0	3.6	5.10	4.78	0.58	.018	1,150
1031	" 24	"	.20	.0068	.0034	.0000	.0375	2.90	12.4	0.0	4.0	5.28	4.46	0.58	.014	550
1050	" 31	"	.20	.0050	.0010	.0000	.0525	3.42	11.2	0.0	3.4	5.25	4.40	0.79	.018	520
	Av'gs,	.....	.16	.0051	.0020	.0000	.0270	3.12	11.5	0.0	3.1	4.77	4.13	0.57	.016	850

Effluent—Hulton Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
1075	June 7	Clear	.12	.0040	.0016	.0000	.0450	4.00	14.0	0.0	4.0	6.22	5.10	1.07	.004	1,260
1098	" 14	Slight	.17	.0040	.0018	.0000	.0225	4.72	14.6	0.3	3.4	6.08	5.58	1.47	.008	300
1125	" 21	Clear	.12	.0046	.0008	.0000	.0225	5.13	15.6	0.0	4.4	6.00	6.13	0.28	.009	75
1154	" 28	"	.10	.0040	.0018	.0000	.0450	4.61	15.8	0.0	3.6	6.36	5.94	0.89	.008	320
	Av'gs,	.....	.13	.0041	.0015	.0000	.0337	4.61	15.0	0.1	3.8	6.16	5.69	0.93	.007	490
1174	July 6	Clear	.17	.0040	.0024	.0000	.0975	3.76	13.8	0.0	3.6	6.10	5.50	0.38	.010	2,450
1200	" 12	"	.27	.0048	.0016	.0000	.0675	3.27	13.4	0.0	4.0	5.84	5.20	1.20	.006	6,420
1222	" 19	"	.20	.0040	.0016	.0000	.0675	5.40	19.6	0.0	5.0	7.28	6.55	0.89	.008	17,100
1247	" 26	"	.22	.0058	.0014	.0000	.0525	3.88	16.2	0.0	5.4	6.39	5.34	1.82	.010	17,800
	Av'gs,	.....	.21	.0046	.0017	.0000	.0712	4.08	15.7	0.0	4.5	6.40	5.65	1.07	.008	10,950
1276	Aug. 2	Slight	.20	.0040	.0016	.0000	.0525	4.34	18.2	0.6	5.6	7.30	6.62	1.34	.018	14,800
1298	" 9	Clear	.20	.0062	.0016	.0000	.0525	4.75	17.8	0.0	5.0	8.14	7.16	1.10	.014	250
1328	" 16	"	.10	.0040	.0022	.0000	.0525	4.60	16.0	0.0	3.0	7.00	6.62	0.92	.016	300
1364	" 23	"	.20	.0062	.0022	.0000	.0300	3.68	13.6	0.0	3.5	5.62	5.58	0.79	.004	100
	Av'gs,	.....	.17	.0051	.0019	.0000	.0469	4.34	16.4	0.1	4.3	7.01	6.49	1.04	.013	3,860

VERONA TAP.

Samples of the "Tap Water" supplied in Verona were collected once a week, during the months of August to November, inclusive, 1897, then once in two weeks to May 1, 1898, and thereafter once a week, until the close of the experiments. The water supply is pumped a distance of about three miles to the village, and into the distributing system; the surplus passing into a reservoir of 1,500,000 gallons capacity. The samples were collected from a tap near the railroad station.

Verona Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.	Chlorine.	Total.	Suspended.	Loss on Ignition.				
	1897.														
95	Aug. 9	Clear	....	.0106	.0007	.0000	.0600	4.30	15.4	...	5.1	7.60	11.72	1.07 .035	126
117	" 16	"	...	.0066	.0018	.0000	.0375	4.50	15.2	...	4.0	10.45	7.67	0.86 .020	81
181	" 30	"	.10	.0104	.0018	.0000	.0900	3.70	13.0	...	4.2	7.03	6.78	1.27 .030	84
	Av'gs,	.....	.10	.0092	.0014	.0000	.0625	4.17	14.5	...	4.4	8.36	8.72	1.07 .028	97
219	Sept. 7	V.sl'gt.	.15	.0104	.0012	.0000	.0375	3.73	15.4	...	2.8	5.97	7.13	0.72 .008	20
235	" 14	Clear	.15	.0102	.0014	.0000	.0488	2.89	14.8	...	4.8	6.79	6.45	1.16 .010	17
267	" 22	"	.00	.0104	.0012	.0000	.0375	3.44	15.8	...	4.8	6.34	6.19	0.86 .004	134
297	" 28	"	.00	.0098	.0007	.0000	.0750	4.38	19.6	...	7.2	7.25	7.16	1.96 .020	1,050
	Av'gs,	.....	.07	.0102	.0011	.0000	.0497	3.61	16.4	...	4.9	6.59	6.73	1.17 .010	305
330	Oct. 5	Clear	.20	.0106	.0018	.0000	.0900	4.16	20.8	...	7.6	7.69	7.35	1.82 .044	1,783
359	" 12	V.sl'gt.	.10	.0146	.0010	.0000	.0600	3.64	18.8	...	8.8	5.80	5.42	2.02 .022	1,820
380	" 19	Clear	.10	.0085	.0012	.0000	.0675	3.58	18.0	...	6.4	5.75	5.21	2.06 .040	1,442
412	" 26	"	.10	.0076	.0014	.0000	.0375	4.43	21.6	...	8.8	5.48	5.28	2.09 .006	1,778
	Av'gs,	.....	.12	.0103	.0013	.0000	.0637	3.95	19.8	...	7.9	6.18	5.81	2.00 .028	1,706
438	Nov. 2	Clear	.10	.0130	.0014	.0000	.0375	5.42	18.8	0.0	6.4	5.90	5.55	1.72 .004	2,600
472	" 9	"	.10	.0108	.0018	.0000	.0450	5.11	18.8	0.0	6.8	6.08	5.90	2.30 .004	210
493	" 16	"	.05	.0168	.0026	.0000	.0600	5.06	22.8	0.0	8.8	6.94	6.33	1.58 .004	87
530	" 23	"	.20	.0064	.0014	.0000	.0375	5.99	20.8	0.0	6.4	2.06	6.39	1.72 .006	79
	Av'gs,	.....	.11	.0117	.0018	.0000	.0450	5.39	20.3	0.0	7.1	5.24	6.04	1.83 .004	744
562	Dec. 7	Clear	.10	.0064	.0014	.0000	.0825	6.51	20.0	0.0	6.8	8.19	7.05	0.79 .002	175
599	" 21	"	.10	.0052	.0010	.0000	.0375	6.25	20.8	0.0	6.4	6.90	6.45	1.27 .006	...
	Av'gs,	.....	.10	.0058	.0012	.0000	.0600	6.38	20.4	0.0	6.6	7.54	6.75	1.03 .004	175
	1898.														
630	Jan. 4	V.sl'gt.	.10	.0040	.0022	.0000	.0675	2.60	23.2	0.0	9.2	7.16	6.51	1.23 .004	444
670	" 18	Clear	.00	.0038	.0026	.0000	.0600	5.21	20.4	0.0	7.2	6.40	5.76	0.89 .008	323
	Av'gs,	.....	.05	.0039	.0024	.0000	.0637	3.90	21.8	0.0	8.2	6.78	6.13	1.06 .006	383

Verona Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
705	Feb. 1	Clear	.15	.0032	.0014	.0000	.0825	4.92	17.2	0.0	6.9	5.80	5.50	0.61	.008	1,980
748	" 16	"	.07	.0042	.0010	.0000	.0750	4.92	15.2	0.0	4.8	6.04	5.28	0.92	.008	130
	Av'gs,	.....	.11	.0037	.0012	.0000	.0787	4.92	16.2	0.0	5.8	5.92	5.39	0.76	.008	1,055
785	Mar. 1	Clear	.10	.0044	.0022	.0000	.0450	4.68	16.0	0.0	5.6	6.44	5.40	1.07	.008	37
822	" 15	"	.15	.0034	.0008	.0000	.0450	4.20	14.8	0.0	3.6	6.44	5.45	0.48	.012	160
855	" 29	"	.12	.0068	.0030	.0000	.0450	4.48	16.4	0.6	6.2	6.22	5.32	0.68	.012	1,267
	Av'gs,	.....	.12	.0049	.0020	.0000	.0450	4.45	15.7	0.2	5.1	6.37	5.39	0.74	.011	488
895	Apr. 12	V.sl'gt.	.17	.0058	.0014	.0000	.0675	4.23	14.4	0.0	3.6	5.40	4.60	0.68	.010	560
933	" 26	Clear	.15	.0062	.0018	.0000	.0525	3.62	13.0	0.0	4.4	4.66	4.37	0.58	.010	560
	Av'gs,	.....	.16	.0060	.0016	.0000	.0600	3.92	13.7	0.0	4.0	5.03	4.48	0.63	.010	560
979	May 10	V.sl'gt.	.20	.0050	.0016	.0000	.0300	3.26	14.4	0.0	4.4	4.32	4.16	0.55	.015	920
1001	" 17	Clear	.12	.0042	.0012	.0000	.0075	3.25	12.0	0.0	3.4	5.22	4.52	0.58	.006	...
1032	" 24	"	.20	.0072	.0018	.0000	.0300	2.78	12.2	0.0	3.6	5.20	4.36	0.58	.004	620
1051	" 31	"	.10	.0054	.0006	.0000	.0450	3.40	11.6	0.0	4.2	5.30	4.50	0.52	.004	800
	Av'gs,	.....	.15	.0054	.0013	.0000	.0281	3.17	12.5	0.0	3.9	5.01	4.38	0.56	.007	780
1076	June 7	Clear	.15	.0042	.0008	.0000	.0225	4.30	14.8	0.0	4.0	6.18	5.28	0.58	.003	2,800
1099	" 14	V.sl'gt.	.17	.0038	.0018	.0000	.0225	4.22	14.9	0.2	3.9	5.68	5.46	0.34	.010	375
1128	" 21	Clear	.17	.0078	.0012	.0000	.0300	4.65	17.2	0.0	4.6	5.80	5.90	0.41	.006	300
1155	" 29	"	.10	.0044	.0010	.0000	.0450	4.90	16.8	0.0	4.6	6.44	6.10	0.89	.009	41
	Av'gs,	.....	.15	.0050	.0012	.0000	.0300	4.52	15.9	0.0	4.3	6.02	5.68	0.55	.007	880
1175	July 6	Clear	.17	.0044	.0020	.0000	.0750	3.88	14.2	0.0	5.4	6.18	5.62	0.24	.008	76
1201	" 12	"	.27	.0050	.0016	.0000	.0750	4.38	16.2	0.0	5.0	6.32	5.90	1.20	.008	3,360
1223	" 19	"	.20	.0048	.0012	.0000	.0675	4.41	16.9	0.0	4.1	6.18	5.90	0.79	.012	8,400
1248	" 26	"	.22	.0052	.0018	.0000	.0450	4.48	18.0	0.0	5.4	6.62	5.80	1.72	.008	1,000
	Av'gs,	.....	.21	.0048	.0016	.0000	.0656	4.29	16.3	0.0	5.0	6.32	5.80	0.99	.009	3,210

Verona Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
1277	Aug. 2	Slight	.20	.0040	.0014	.0000	.0450	4.92	18.4	0.9	4.9	7.20	6.43	1.03	.010	7,650
1299	" 9	Clear	.20	.0058	.0022	.0000	.0525	4.70	17.3	0.0	5.4	8.20	7.12	1.16	.010	325
1338	" 16	"	.20	.0048	.0022	.0000	.0525	4.62	16.0	0.0	4.8	6.80	6.25	1.13	.004	520
1363	" 23	"	.20	.0054	.0024	.0000	.0300	3.72	14.6	0.0	4.2	6.50	5.48	0.75	.002	300
	Av'gs,	.....	.20	.0050	.0020	.0000	.0450	4.49	16.6	0.2	4.8	7.17	6.32	1.02	.006	2,200

ALLEGHENY RIVER AT WILDWOOD.

Samples were collected of the "Allegheny River at Wildwood," about one and one-half miles above Brilliant, once a week from the last of June to the last of October, 1897, and once in November, 1897. After this the samples collected at Brilliant may be taken as representing the river at Wildwood.

The water supply of Wilkinsburg, some neighboring towns, and of the 37th Ward of Pittsburgh, is furnished by the Pennsylvania Water Company. The water is obtained from the Allegheny River at Wildwood and, since June, 1897, from a crib situated in the middle of the river. This crib is connected, by a 24-inch pipe in the bed of the river, with a tunnel on the shore, reaching from the low water mark to the pump well. The crib is 304 feet long, 32 feet wide, and 4 feet deep, and is built of 2-inch x 8-inch planks, with two-inch open spaces on the top and sides, and nothing on the bottom. The bed of the stream was dredged and the crib floated out and sunk. Upon the crib and all around it there was placed one foot of large stones, then one foot of coarse gravel, and then three feet of river sand.

It is said, that underneath the crib there is thirty feet of gravel in the bed of the stream. The average daily pumpage is about 1,500,000 gallons. These samples were collected from a boat over the crib.

Allegheny River at Wildwood.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
20	June 23	.....	...	.0120	.0000	.0000	.0000	1.60	10.0	...	6.0	7.60	...	1.40	.000	.....
35	July 7	.....	...	.0180	.0050	.0000	.0000	2.50	13.2	...	6.0	6.20	...	1.04	...	.....
43	" 13	Slight	...	.0162	.0016	.0003	.0015	1.80	12.4	0.8	5.6	4.97	7.50	1.35	.002	520
53	" 19	"	...	.0182	.0013	.0002	.0610	1.47	14.4	3.6	6.2	5.75	6.50	0.96	.050	.....
69	" 29	Mud'y	...	.0280	.0031	.0000	.1334	0.95	22.9	13.9	4.0	4.07	4.50	0.89	.110	11,350
	Av'gs,	.....	...	.0201	.0027	.0001	.0490	1.68	15.7	4.6	5.4	5.25	6.16	1.06	.054	5,935
85	Aug. 4	Slight	...	.0240	.0030	.0001	.0950	1.15	10.8	1.1	4.0	4.13	5.70	0.76	.120	1,225
102	" 11	Mud'y	...	.0395	.0035	.0000	.0814	3.75	44.8	28.2	9.6	5.80	6.15	1.03	.180	3,600
123	" 18	Slight	...	.0268	.0018	.0000	.0600	1.56	20.0	10.6	3.0	6.72	4.51	0.74	.220	11,200
148	" 24	V. sl'gt	...	.0204	.0028	.0000	.0450	1.31	8.6	...	4.2	5.30	3.65	1.00	.020	5,200
176	" 30	V. "	.40	.0141	.0009	.0000	.0600	1.68	10.4	...	4.8	6.51	4.50	1.03	.030	6,500
	Av'gs,	.....	.40	.0250	.0024	.0000	.0683	1.89	18.9	8.0	5.1	5.69	4.90	0.91	.114	5,545
209	Sept. 7	V. sl'gt	.40	.0122	.0014	.0000	.0600	1.88	11.2	...	4.4	5.42	4.90	1.44	.026	7,425
242	" 14	Slight	.20	.0112	.0012	.0000	.0575	2.14	13.2	...	5.6	6.18	5.40	1.30	.026	300
257	" 21	"	.25	.0108	.0028	.0000	.0300	2.62	16.0	...	5.6	5.70	5.40	1.72	.034	825
291	" 27	"	.25	.0118	.0012	.0000	.0675	2.51	14.0	...	4.0	3.70	3.77	3.13	.046	3,600
	Av'gs,	.....	.27	.0115	.0016	.0000	.0537	2.29	13.6	...	4.9	5.25	4.87	1.90	.033	3,037
319	Oct. 5	Slight	.35	.0100	.0012	.0000	.0775	2.89	15.2	...	7.0	5.13	4.68	2.41	.046	3,375
344	" 11	V. sl'gt	.25	.0158	.0020	.0000	.0450	2.97	17.6	...	6.4	4.56	4.62	2.09	.064	13,400
381	" 18	Slight	.20	.0120	.0020	.0000	.0750	2.98	15.6	...	4.8	4.90	4.64	2.64	.030	117,500
403	" 25	V. sl'gt	.20	.0070	.0018	.0000	.0750	3.83	17.6	...	6.0	5.40	5.17	2.51	.044	74,900
	Av'gs,	.....	.25	.0112	.0017	.0000	.0681	3.17	16.5	...	6.0	5.00	4.78	2.41	.046	52,294
538	Nov. 29	Clear	.00	.0068	.0010	.0000	.0600	2.75	18.8	0.0	8.2	8.31	7.81	1.37	.016	.....

EFFLUENT—WILDWOOD CRIB.

Samples were collected from the water which had passed through this crib, about once a week during the work, except in March and April, 1898, when the pump was not running in the day time and it was inconvenient to secure samples. These samples were collected from a tap upon a three-quarter-inch pipe, which was connected with the force main just outside the pumping station.

Effluent—Wildwood Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
21	June 23	.....	...	.0040	.0000	.0000	.0000	2.00	14.4	...	8.8	10.00	...	1.58	.000	...
36	July 7	.....	...	.0070	.0050	.0000	.0000	2.10	14.8	...	6.4	8.00	...	1.07	...	...
44	" 13	Clear	...	.0046	.0012	.0001	.0010	1.85	16.0	...	6.8	7.30	8.00	0.92	.005	269
54	" 19	"	...	.0058	.0024	.0003	.0300	2.31	17.3	...	6.9	9.40	16.00	1.14	.020	...
71	" 29	"	...	.0032	.0023	.0005	.0445	2.20	14.5	...	4.3	9.10	17.50	0.87	.005	59
	Av'gs,	.....	. .	.0051	.0027	.0002	.0189	2.11	15.6	...	6.1	8.45	13.83	1.00	.010	164
86	Aug. 4	Clear	...	.0062	.0018	.0004	.0592	1.45	15.0	...	5.2	9.15	17.90	0.52	.010	88
103	" 11	"	...	.0110	.0024	.0003	.0370	2.12	14.0	...	5.0	9.92	17.35	0.69	.015	50
124	" 18	"	...	.0052	.0023	.0003	.0300	1.81	14 6	...	2.0	9.78	11.10	0.88	.008	262
149	" 24	"	...	.0060	.0028	.0000	.0375	1.99	13.6	...	6.4	9.42	10.70	0.86	.002	106
177	" 30	"	.15	.0070	.0025	.0000	.0450	1.99	14.4	...	6.0	9.76	10.12	0.82	.100	188
	Av'gs,	.....	.15	.0071	.0024	.0002	.0417	1.87	14.3	...	4.9	9.61	13.43	0.75	.027	139
210	Sept. 7	Clear	.20	.0048	.0026	.0001	.0450	2.03	12.8	...	4.0	8.36	9.85	0.81	.012	78
243	" 14	"	.00	.0062	.0018	.0000	.2250	2.19	14.6	...	4.8	8.50	10.01	0.89	.020	12
258	" 21	"	.00	.0056	.0012	.0000	.0225	2.15	15 4	...	6.8	7.10	11.11	1.03	.010	160
292	" 27	"	.00	.0040	.0014	.0000	.0450	2.62	15 6	...	6.8	10.54	10.68	1.68	.004	148
	Av'gs,	.....	.05	.0051	.0017	.0000	.0844	2.25	14.6	...	5.6	8.62	10.41	1.10	.011	99

Effluent—Wildwood Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
320	Oct. 5	Clear	.00	.0038	.0012	.0000	.0825	2.78	18.4	...	8.0	9.70	8.65	1.51	.018	116
345	" 11	"	.00	.0064	.0014	.0000	.0525	2.85	16.8	...	8.4	9.38	8.68	1.37	.020	542
382	" 18	"	.00	.0040	.0012	.0000	.0750	2.88	18.0	...	6.0	8.90	8.75	1.96	.004	1,988
404	" 25	"	.00	.0020	.0012	.0000	.0375	3.27	17.2	...	4.0	8.64	8.55	1.65	.024	4,120
	Av'gs,	.....	.00	.0041	.0012	.0000	.0619	2.94	17.6	...	6.6	9.15	8.66	1.62	.016	1,691
432½	Nov. 1	Clear	.00	.0046	.0022	.0000	.0525	3.20	20.4	0.0	7.6	9.52	9.06	1.75	.005	3,980
469	" 8	"	.00	.0038	.0018	.0000	.0450	3.20	21.8	0.0	8.2	8.96	8.71	2.06	.003	580
489	" 15	.....	.00	.0068	.0032	.0000	.0075	3.38	21.6	0.0	8.6	9.40	8.78	2.06	.022	172
525	" 23	Slight	.20	.0072	.0014	.0000	.0300	4.84	20.4	0.0	10.4	8.01	7.34	1.65	.016	260
	Av'gs,	.....	.05	.0056	.0021	.0000	.0337	3.65	21.0	0.0	8.7	8.97	8.47	1.88	.011	1,248
555	Dec. 6	Clear	.00	.0076	.0014	.0000	.0750	3.00	21.6	0.0	9.2	9.26	8.89	1.58	.008	68
597	" 20	"	.00	.0038	.0012	.0000	.0525	2.55	17.2	0.0	5.8	8.90	7.99	1.44	.012	181
613	" 28	"	.00	.0032	.0018	.0000	.0525	2.54	17.2	0.0	6.8	8.23	7.90	1.44	.015	1,498
	Av'gs,	.....	.00	.0049	.0015	.0000	.0600	2.70	18.7	0.0	7.3	8.80	8.26	1.49	.012	582
	1898.															
631	Jan. 4	Clear	.00	.0038	.0024	.0000	.0600	5.51	19.2	0.0	8.4	8.87	8.12	1.58	.004	546
642	" 10	"	.00	.0020	.0012	.0000	.1200	2.44	20.8	0.0	9.2	8.68	8.07	1.61	.008	482
668	" 18	"	.00	.0060	.0024	.0000	.0600	1.52	12.6	0.0	5.8	4.22	3.88	1.10	.040	3,120
	Av'gs,	.....	.00	.0039	.0020	.0000	.0800	3.16	17.5	0.0	7.8	7.26	6.69	1.43	.017	1,383
858	Mar. 30	V. sl'gt	.25	.0052	.0016	.0000	.0525	1.28	10.0	0.0	3.2	3.28	2.99	0.89	.041	889
935	Apr. 26	Clear	.10	.0068	.0018	.0000	.0375	1.60	10.0	0.0	4.4	5.90	5.01	0.96	.030	575
959	May 3	Clear	.10	.0048	.0022	.0000	.0000	1.52	10.8	0.0	4.2	5.68	5.16	0.85	.008	525
980	" 10	"	.10	.0068	.0018	.0000	.0300	1.50	10.8	0.0	3.2	6.15	5.70	0.92	.010	365
1002	" 17	"	.05	.0042	.0016	.0000	.0075	1.74	12.8	0.0	3.4	6.70	6.18	1.16	.008	1,650
1052	" 31	Slight	.45	.0058	.0020	.0000	.0450	1.44	11.4	0.8	4.0	6.28	5.80	1.13	.014	.....
	Av'gs,	.....	.17	.0054	.0019	.0000	.0206	1.55	11.4	0.2	3.7	6.20	5.71	1.01	.010	850

Effluent—Wildwood Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
1104	June 14	V. sl'gt.	.17	.0048	.0012	.0000	.0300	1.94	13.4	0.0	4.6	6.98	6.70	1.47	.010	800
1151	" 27	Clear	.10	.0038	.0016	.0000	.0525	1.92	12.8	0.0	3.0	7.33	6.90	0.79	.008	220
	Av'gs,	.....	.13	.0043	.0014	.0000	.0412	1.93	13.1	0.0	3.8	7.15	6.80	1.13	.009	510
1183	July 7	Clear	.10	.0048	.0018	.0000	.1050	1.60	12.6	0.0	4.1	7.32	6.96	1.23	.014	720
1202	" 12	"	.17	.0038	.0016	.0000	.0600	2.00	14.0	0.0	5.4	7.84	7.10	1.27	.006	1,050
1229	" 20	V. sl'gt.	.10	.0038	.0014	.0000	.0675	2.10	14.4	0.0	5.0	7.90	7.06	1.82	.008	1,220
1249	" 26	Clear	.10	.0050	.0018	.0000	.0600	3.16	16.1	0.0	3.8	8.45	7.05	2.51	.006	500
	Av'gs,	.....	.12	.0043	.0016	.0000	.0731	2.21	14.3	0.0	4.6	7.88	7.04	1.71	.008	870
1279	Aug. 2	Slight	.20	.0038	.0016	.0000	.0600	2.92	37.0	9.8	4.6	8.26	7.54	1.65	.008	850
1300	" 9	Clear	.17	.0064	.0014	.0000	.0450	1.96	21.6	0.0	7.2	8.34	7.64	4.02	.012	8,700
1339	" 16	"	.20	.0044	.0020	.0000	.0600	2.05	16.2	0.0	5.0	9.04	7.94	1.54	.006	425
1365	" 23	V. sl'gt.	.17	.0048	.0024	.0000	.0225	1.62	16.2	0.8	5.0	8.54	6.20	2.55	.008	3,900
	Av'gs,	.....	.18	.0048	.0018	.0000	.0469	2.14	22.7	2.6	5.4	8.54	7.33	2.44	.008	3,470

WILKINSBURG TAP.

Samples of the "Tap Water" in Wilkinsburg were collected once a week during the months of September, October and November, 1897, and then about once a month until the close of the experiments. The water supply is pumped from Wildwood to an open reservoir of 6,000,000 gallons capacity, about one mile distant from the river. From this basin it is distributed throughout the service system. The samples were collected from a tap near the corner of Wood Street and Penn Avenue.

Wilkinsburg Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as. Albuminoid Ammonia.	Nitrogen as. Free Ammonia.	Nitrogen as. Nitrites.	Nitrogen as. Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897															
232	Sept. 13	Clear	.20	.0086	.0018	.0000	.0150	2.07	12.8	...	4.4	9.55	9.21	1.27	.016	18
259	" 21	"	.00	.0060	.0010	.0000	.0488	2.56	15.8	...	6.4	9.02	9.66	0.99	.020	14
285	" 27	"	.10	.0072	.0012	.0000	.0300	2.59	16.8	...	7.2	9.50	9.97	0.99	.018	58
	Av'gs,	.....	.10	.0073	.0013	.0000	.0313	2.41	15.1	...	6.0	9.36	9.61	1.08	.018	30
312	Oct. 4	Clear	.30	.0076	.0016	.0000	.0600	2.57	18.0	...	7.6	10.91	10.53	1.75	.015	148
343	" 11	"	.30	.0072	.0010	.0000	.1275	2.63	18.0	...	7.2	9.76	8.62	1.47	.005	311
369	" 18	"	.00	.0078	.0018	.0000	.1350	3.05	18.0	...	7.2	10.80	9.10	1.78	.014	.....
398	" 25	V. sl'gt	.00	.0080	.0028	.0000	.0375	3.02	19.2	...	5.2	8.94	8.60	1.72	.032	2,820
	Av'gs,	.....	.15	.0076	.0018	.0000	.0900	2.82	18.3	...	6.8	10.10	9.21	1.68	.016	1,093
428	Nov. 1	Slight	.00	.0140	.0024	.0000	.0375	3.54	18.8	0.4	9.6	9.60	9.31	1.92	.004	13,860
460	" 8	Clear	.00	.0076	.0016	.0000	.0600	3.30	22.4	0.0	8.8	8.90	8.90	2.13	.008	775
488	" 15	"	.00	.0086	.0026	.0000	.0150	3.69	20.8	0.0	9.6	9.54	8.92	1.92	.008	236
508	" 22	Slight	.10	.0058	.0008	.0000	.0600	2.66	20.4	0.2	4.8	8.34	7.73	1.68	.036	100
	Av'gs,	.....	.02	.0090	.0018	.0000	.0431	3.30	20.6	0.1	8.2	9.09	8.71	1.91	.014	3,743
554	Dec. 6	Dec'd	.20	.0088	.0014	.0000	.0750	2.90	22.4	2.6	7.6	10.32	9.20	1.27	.116	280
589	" 20	Mud'y	.20	.0148	.0012	.0000	.0525	2.95	33.6	13.2	4.8	9.03	8.70	1.47	.330	.....
	Av'gs,	.....	.20	.0118	.0013	.0000	.0637	2.92	28.0	7.9	6.2	9.67	8.95	1.37	.223	280
	1898.															
659	Jan. 17	Slight	.20	.0080	.0014	.0000	.0750	1.26	10.8	0.2	3.6	2.40	2.01	1.27	.120	5,340
736	Feb. 14	Slight	.12	.0048	.0022	.0000	.2325	1.48	12.8	0.4	5.6	5.22	4.21	1.47	.085	2,562
936	Apr. 26	Clear	.15	.0062	.0012	.0000	.0375	1.51	12.0	0.0	5.2	6.38	5.70	1.13	.010	274
1216	July 18	Slight	.20	.0046	.0018	.0000	.0600	2.55	15.8	0.4	5.2	7.32	6.88	1.34	.010	540
1252	" 27	V. sl'gt	.17	.0056	.0018	.0000	.0525	3.24	16.0	0.0	4.5	8.40	7.10	2.41	.006	1,100
	Av'gs,	.....	.18	.0051	.0018	.0000	.0562	2.89	15.9	0.2	4.8	7.86	6.99	1.87	.008	820

EFFLUENT—SHARPSBURG CRIB.

Samples were collected of the water after passing through this crib, once a week in May, 1898, and once in two weeks during the months of June, July, and August, 1898. The water supply for Sharpsburg is derived from the Allegheny River, about one mile below Brilliant on the opposite side. Since 1893, a crib, 100 feet long, 8 feet wide, and 5 feet deep, has been in use; which is connected with the pump well by an 18-inch pipe, 800 feet long. The crib has about two and one-half feet of river material over it, but is made tight down two and one-half feet; the remainder of the sides and the bottom being open. The width of timbers and of openings is six inches. Low water mark is about three feet above the top of the crib. The water is delivered directly into the piping system from the pumps. The samples were collected from a tap upon the pumps.

Effluent—Sharpsburg Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
957	May 3	Clear	.17	.0042	.0018	.0000	.0450	1.85	15.2	0.0	4.0	4.88	4.70	1.20	.028	2,300
981	" 10	Slight	.22	.0090	.0022	.0000	.0225	1.41	12.0	0.4	4.0	5.08	3.96	1.54	.030	4,300
1012	" 17	Clear	.20	.0036	.0020	.0000	.0225	2.30	25.2	0.0	11.4	10.80	7.10	2.93	.012	800
1056	" 31	Slight	.27	.0056	.0018	.0000	.0600	2.00	15.5	0.0	5.0	6.60	4.70	1.27	.015	7,450
	Av'gs,	.....	.21	.0056	.0019	.0000	.0375	1.89	17.0	0.1	6.1	6.84	5.11	1.73	.021	3,710
1080	June 7	V.sl'gt	.20	.0068	.0014	.0000	.0300	2.18	11.2	0.0	3.6	4.40	3.58	1.03	.004	20,500
1132	" 21	Dec'd	.40	.0180	.0018	.0000	.0300	1.70	26.8	15.4	4.5	4.08	3.60	1.41	.040	11,100
	Av'gs,	.....	.30	.0124	.0016	.0000	.0300	1.94	19.0	7.7	4.0	4.24	3.59	1.22	.022	15,800
1180	July 6	Slight	.30	.0104	.0016	.0000	.0750	1.70	11.8	0.8	4.6	3.95	3.87	1.27	.020	13,800
1226	" 19	V.sl'gt.	.20	.0088	.0016	.0000	.0750	2.40	13.2	0.0	3.4	4.90	4.18	2.06	.010	13,000
	Av'gs,	.....	.25	.0096	.0016	.0000	.0750	2.05	12.5	0.4	4.0	4.42	4.02	1.66	.015	13,400

Effluent—Sharpsburg Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
1273	Aug. 2	Slight	.25	.0064	.0018	.0000	.0525	2.48	20.8	1.2	7.0	5.62	4.82	1.92	.016	32,200
1337	" 16	"	.30	.0106	.0020	.0000	.0525	1.98	14.4	2.6	3.8	5.14	4.02	1.38	.010	18,800
	Av'gs,	.....	.27	.0085	.0019	.0000	.0525	2.23	17.6	1.9	5.4	5.38	4.42	1.65	.013	25,500

ALLEGHENY RIVER AT ETNA.

Samples were collected of the "Allegheny River at Etna," two miles below Brilliant upon the opposite side, once a week during the months of August to November, inclusive, 1897; then once in two weeks for the next three months, and occasionally during the remaining time.

The water supply of Etna is derived from the river at this point and, since January, 1898, from a crib situated in the river, and connected with the pumps by a 12-inch suction pipe. The crib is a wooden box, 40 feet long, 16 feet wide, and 4 feet deep, perforated with many openings. It was sunk in place and covered with stone, river gravel, and sand, about four feet deep. The average daily pumpage is about 350,000 gallons. The samples were collected from lumber rafts moored to the shore.

Allegheny River at Etna.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
104	Aug. 11	Mud'y	....	.0420	.0036	.0000	.0444	1.43	46.0	34.8	6.0	5.72	6.61	1.00	.180	.....
125	" 18	Slight	....	.0254	.0018	.0000	.0525	1.74	20.0	10.4	5.6	7.22	5.25	0.86	.240	7,150
155	" 24	"	....	.0176	.0016	.0000	.0937	1.16	9.2	...	3.6	5.46	3.81	1.10	.034	5,600
173	" 30	"	.40	.0176	.0009	.0000	.0600	1.65	9.8	...	3.2	5.85	4.31	1.23	.050	6,850
	Av'gs,	.....	.40	.0256	.0020	.0000	.0626	1.49	21.2	11.3	4.6	6.06	4.99	1.05	.126	6,533

Allegheny River at Etna.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
207	Sept. 7	Slight	.40	.0222	.0028	.0000	.0750	2.10	10.8	...	4.4	5.22	5.04	1.20	.032	6,125
237	" 14	"	.25	.0138	.0016	.0000	.0412	2.10	13.2	...	5.6	7.05	5.87	1.61	.024	4,456
264	" 21	"	.20	.0186	.0012	.0000	.0600	2.80	15.0	...	7.6	5.98	5.51	1.51	.048	2,625
299	" 28	V. sl'gt.	.30	.0118	.0024	.0000	.0812	2.21	17.6	...	6.8	3.84	3.77	2.95	.062	5,250
	Av'gs,	.....	.29	.0166	.0020	.0000	.0643	2.30	14.1	...	6.1	5.52	5.05	1.82	.041	4,614
328	Oct. 5	V. sl'gt.	.30	.0188	.0014	.0000	.0900	2.94	15.6	...	5.6	5.73	5.45	2.34	.050	7,200
354	" 12	V. "	.30	.0160	.0032	.0000	.0600	3.20	17.2	...	7.2	5.36	4.90	1.85	.048	28,750
386	" 19	V. "	.20	.0122	.0022	.0000	.0600	4.61	18.0	...	7.2	5.12	4.96	2.75	.040	27,300
414	" 26	V. "	.20	.0144	.0048	.0000	.0750	4.00	22.0	...	10.4	5.94	5.65	2.64	.038	75,000
	Av'gs,	.....	.25	.0153	.0029	.0000	.0712	3.69	18.2	...	7.6	5.54	5.26	2.39	.044	34,562
443	Nov. 2	Slight	.20	.0120	.0048	.0000	.0450	4.73	24.0	0.0	8.0	5.98	5.74	2.13	.062	.....
474	" 8	Clear	.25	.0144	.0038	.0000	.0450	3.95	19.2	0.4	6.4	5.21	4.93	2.50	.086	34,000
497	" 16	.....	.35	.0288	.0240	.0000	.0900	2.53	26.4	7.2	7.2	5.90	5.10	2.02	.264	40,950
527	" 24	V. sl'gt.	.30	.0144	.0020	.0000	.0375	2.13	11.6	0.3	3.6	2.93	2.37	1.37	.086	13,700
546	" 30	.....	.30	.0154	.0016	.0000	.0975	1.27	16.4	5.6	6.4	2.73	2.22	0.96	.116	48,000
	Av'gs,	.....	.28	.0170	.0072	.0000	.0630	2.92	19.5	2.7	6.3	4.55	4.07	1.80	.123	34,162
583	Dec. 14	Dec'd	.30	.0108	.0028	.0000	.0675	1.39	16.0	3.6	6.4	2.86	2.30	1.30	.112	42,500
616	" 28	V. sl'gt.	.30	.0096	.0036	.0000	.0825	1.80	11.6	0.6	3.6	2.42	2.14	1.65	.076	27,400
	Av'gs,	.....	.30	.0102	.0032	.0000	.0750	1.59	13.8	2.1	5.0	2.64	2.22	1.47	.094	34,950
	1898.															
647	Jan. 11	Slight	.30	.0088	.0028	.0000	.1425	1.38	14.8	2.4	4.4	2.64	2.13	1.61	.138	.....
687	" 25	V. sl'gt.	.25	.0106	.0012	.0000	.1200	0.93	11.6	4.8	4.0	1.68	1.44	0.44	.045	30,600
	Av'gs,	.....	.27	.0097	.0020	.0000	.1312	1.15	13.2	3.6	4.2	2.16	1.78	1.02	.091	30,600
726	Feb. 7	Clear	.25	.0052	.0026	.0000	.1500	1.32	10.2	0.0	4.0	3.16	2.18	1.34	.045	3,000
765	" 22	Slight	.27	.0048	.0018	.0000	...	1.20	10.8	0.4	2.8	3.16	2.05	1.27	.016	18,600
	Av'gs,	.....	.26	.0050	.0022	.0000	.1500	1.26	10.5	0.2	3.4	3.16	2.11	1.30	.030	10,800

Allegheny River at Etna.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
836	Mar. 22	Mud'y	.20	.0210	.0016	.0000	.0525	0.92	52.8	40.8	4.4	2.33	1.80	0.58	.108	.....
915	Apr. 19	V.sl'gt.	.17	.0062	.0022	.0000	.0375	1.45	10.8	0.4	4.4	3.11	2.68	1.30	.050	9,100
954	May 3	V.sl'gt.	.27	.0088	.0020	.0000	.0225	1.60	8.2	0.2	2.4	2.90	2.50	0.49	.046	6,900
983	" 10	Slight	.25	.0080	.0028	.0000	.0225	1.24	8.6	0.2	3.2	2.84	2.71	0.79	.035	7,700
1008	" 17	Mud'y	.35	.0240	.0032	.0000	.0075	1.10	25.2	16.2	3.4	3.24	2.50	1.38	.046	40,400
1036	" 24	.....	.40	.0120	.0020	.0000	.0300	1.10	14.0	6.8	3.8	2.90	2.42	0.52	.028	17,300
1057	" 31	V.sl'gt.	.32	.0078	.0016	.0000	.0450	1.70	7.4	0.0	3.7	2.80	2.48	0.82	.030	10,400
	Av'gs,	.....	.32	.0121	.0023	.0000	.0255	1.35	12.7	4.7	3.3	2.94	2.52	0.80	.037	16,500
1078	June 7	0.03	.27	.0084	.0042	.0000	.0300	2.38	9.9	0.3	2.6	3.90	3.10	1.03	.002	65,800
1129	" 21	0.90	.32	.0124	.0028	.0000	.0150	1.40	34.1	24.2	3.5	3.38	2.60	1.38	.004	16,400
	Av'gs,	0.46	.29	.0104	.0035	.0000	.0225	1.89	22.0	12.2	3.0	3.64	2.85	1.20	.003	41,100
1177	July 6	0.09	.30	.0130	.0030	.0000	.0750	1.87	12.8	3.9	4.1	3.62	3.30	0.44	.020	1,630
1270	Aug. 2	0.18	.27	.0168	.0036	.0000	.0450	3.00	20.6	7.2	4.6	5.15	4.86	1.58	.026	239,000
1332	" 16	0.16	.30	.0120	.0044	.0000	.0675	1.84	16.0	3.9	4.6	3.98	3.00	0.89	.020	159,000
	Av'gs,	0.17	.28	.0144	.0040	.0000	.0562	2.42	18.3	5.5	4.6	4.56	3.93	1.23	.023	199,000

EFFLUENT—ETNA CRIB.

Samples of water, which had passed through this crib were collected once a week, during the months of August to November, inclusive, 1897, and then, once in two weeks until the close of the experiments. The samples were collected from a petcock upon the pump.

Effluent—Etna Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as.				Chlorine.	Residue on Evaporation.		Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended. Loss on Ignition.					
	1897.														
105	Aug. 11	Dec'd	...	.0176	.0028	.0000	.0629	4.13	30.4	11.0	9.6	10.60	14.30	2.27	.150	525
126	" 18	Clear	...	.0062	.0016	.0000	.1350	4.80	25.2	...	6.3	12.46	9.85	2.51	.040	1,218
156	" 24	"	...	.0076	.0020	.0000	.1687	4.65	23.6	...	8.8	10.90	9.23	2.20	.010	542
174	" 30	Slight	.25	.0118	.0010	.0000	.1313	4.05	18.4	...	7.6	9.81	8.17	1.95	.018	1,372
	Av'gs,	.....	.25	.0108	.0018	.0000	.1245	4.41	24.4	...	8.1	10.94	10.39	2.23	.054	914
208	Sept. 7	Clear	.25	.0126	.0018	.0000	.0975	3.02	16.0	...	4.4	7.62	6.89	1.51	.022	1,288
244	" 15	V. sl'gt	.30	.0122	.0018	.0000	.0900	3.81	17.8	...	6.2	9.48	7.55	2.27	.008	400
265	" 21	V. "	.20	.0118	.0014	.0000	.0900	4.23	21.8	...	9.2	7.50	7.87	1.99	.046	133
300	" 28	V. "	.30	.0098	.0026	.0000	.0900	2.87	24.0	...	9.6	7.50	7.30	2.82	.042	1,841
	Av'gs,	.....	.26	.0116	.0019	.0000	.0919	3.48	19.9	...	7.3	8.02	7.40	2.15	.029	915
329	Oct. 5	Clear	.25	.0090	.0018	.0000	.1500	4.10	22.0	...	8.8	7.94	7.91	3.13	.028	1,652
355	" 12	V. sl'gt	.20	.0148	.0018	.0000	.0750	4.58	24.0	...	10.4	7.26	6.78	2.71	.018	2,730
387	" 19	V. "	.10	.0096	.0010	.0000	.1275	4.83	24.8	...	11.2	7.03	6.81	2.99	.030	13,260
415	" 26	Clear	.20	.0056	.0014	.0000	.0750	4.94	29.6	...	12.4	8.02	7.31	3.19	.026	38,220
	Av'gs,	.....	.19	.0097	.0015	.0000	.1069	4.61	25.1	...	10.7	7.56	7.20	3.00	.025	13,965
444	Nov. 2	Clear	.10	.0172	.0028	.0000	.0300	7.69	33.2	0.0	12.8	7.22	6.97	3.09	.034	.....
475	" 8	V. sl'gt	.20	.0110	.0042	.0000	.0675	5.40	24.8	0.0	9.2	7.78	7.32	3.33	.046	6,900
498	" 16	Slight	.20	.0086	.0018	.0000	.0975	5.76	31.6	0.2	12.4	8.32	6.79	3.61	.058	3,100
528	" 24	Clear	.20	.0110	.0022	.0000	.0825	6.69	34.0	0.0	12.8	9.03	8.35	3.33	.026	2,850
547	" 30	"	.20	.0078	.0010	.0000	.1200	7.97	37.2	0.0	15.6	10.19	9.08	3.64	.006	600
	Av'gs,	.....	.18	.0111	.0024	.0000	.0795	6.70	32.2	0.0	12.6	8.51	7.70	3.40	.034	3,362
584	Dec. 14	V. sl'gt	.10	.0042	.0018	.0000	.0900	7.81	30.4	...	12.0	8.36	7.67	3.13	.010	2,000
617	" 28	Slight	.20	.0030	.0018	.0000	.0825	8.78	36.4	0.0	12.8	10.03	9.01	4.46	.015	.....
	Av'gs,	.....	.15	.0036	.0018	.0000	.0862	8.29	33.4	0.0	12.4	9.19	8.34	3.79	.012	2,000

Effluent—Etna Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
648	Jan. 11	Clear	.05	.0064	.0022	.0000	.1575	8.41	36.8	0.0	14.0	6.04	4.63	3.92	.012	929
688	" 25	"	.00	.0042	.0014	.0000	.1275	6.59	31.2	0.0	12.0	8.17	7.93	3.19	.010	155
	Av'gs,	.....	.02	.0053	.0018	.0000	.1425	7.50	34.0	0.0	13.0	7.10	6.28	3.55	.011	542
727	Feb. 7	Clear	.15	.0044	.0028	.0000	.1575	7.02	31.6	0.0	9.2	9.47	8.05	3.23	.018	300
768	" 22	"	.17	.0038	.0016	.0000	...	7.20	30.0	0.0	8.0	8.24	7.01	3.16	.010	225
	Av'gs,	.....	.16	.0041	.0022	.0000	.1575	7.11	30.8	0.0	8.6	8.85	7.53	3.19	.014	262
801	Mar. 8	V.sl'gt.	.17	.0036	.0020	.0000	.0600	6.55	28.0	0.0	7.6	9.28	8.20	3.16	.008	756
837	" 22	Clear	.15	.0062	.0014	.0000	.0565	5.72	25.2	0.0	9.2	8.62	7.22	...	.010	...
	Av'gs,	.....	.16	.0049	.0017	.0000	.0582	6.13	26.6	0.0	8.4	8.95	7.71	3.16	.009	756
916	Apr. 19	Clear	.12	.0034	.0020	.0000	.0300	4.76	22.8	0.0	7.2	7.00	6.05	2.12	.010	825
955	May 3	Clear	.15	.0036	.0016	.0000	.0450	4.78	21.2	0.0	4.0	7.18	6.55	2.06	.006	150
984	" 10	"	.20	.0038	.0040	.0000	.0225	5.08	23.2	0.0	4.4	9.42	6.95	2.28	.008	250
1009	" 17	"	.15	.0028	.0008	.0000	.0075	4.80	22.6	0.0	7.6	9.18	6.86	2.06	.006	720
1037	" 24	"	.20	.0040	.0022	.0000	.0375	3.91	21.6	0.0	7.4	9.80	6.75	1.72	.018	400
1058	" 31	"	.10	.0064	.0018	.0000	.0375	4.62	20.5	0.0	6.0	8.40	6.32	1.47	.008	770
	Av'gs,	.....	.16	.0041	.0021	.0000	.0300	4.64	21.8	0.0	5.9	8.80	6.69	1.92	.009	460
1079	June 7	Clear	.20	.0040	.0006	.0000	.0300	5.15	19.2	0.0	4.8	6.98	6.15	1.85	.003	5,200
1130	" 21	V.sl'gt	.22	.0030	.0008	.0000	.0225	4.80	23.8	0.0	7.2	7.90	7.42	1.68	.008	325
	Av'gs,	.....	.21	.0035	.0007	.0000	.0262	4.97	21.5	0.0	6.0	7.44	6.78	1.76	.005	2,760
1178	July 6	V.sl'gt	.20	.0058	.0016	.0000	.0675	4.42	20.6	0.0	6.8	7.90	6.86	2.24	.008	1,520
1227	" 19	Clear	.20	.0054	.0014	.0000	.0525	3.92	18.4	0.0	5.2	6.28	5.70	2.47	.014	9,350
	Av'gs,	.....	.20	.0056	.0015	.0000	.0600	4.17	19.5	0.0	6.0	7.09	6.28	2.35	.011	5,450

Effluent—Hulton Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
1271	Aug. 2	Slight	.27	.0066	.0018	.0000	.0450	4.56	23.8	2.8	6.2	8.92	6.98	1.98	.022	12,800
1333	" 16	Clear	.25	.0070	.0026	.0000	.0525	5.41	27.6	0.0	8.2	11.68	9.80	2.38	.018	1,600
	Av'gs,	.....	.26	.0068	.0022	.0000	.0487	4.98	25.7	1.4	7.2	10.30	8.39	2.18	.020	7,200

ETNA TAP.

Samples of "Tap Water" supplied in Etna were collected once in two weeks, during months of October and November, 1897, then once a month until May, 1898, and then once in two weeks until the close of the experiments. The water is pumped directly into the system, the surplus passing into an elevated iron tank. The samples were obtained from a tap upon Bridge Street.

Etna Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
356	Oct. 12	V. sl'gt.	.20	.0136	.0018	.0000	.0975	4.82	22.4	...	10.0	7.25	6.67	1.96	.018	2,450
416	" 26	Clear	.20	.0084	.0012	.0000	.0600	5.11	27.6	...	11.2	7.06	6.99	3.28	.020	22,140
	Av'gs,	.....	.20	.0110	.0015	.0000	.0787	4.96	25.0	...	10.6	7.15	6.83	2.62	.019	12,295
476	Nov. 8	V. sl'gt.	.20	.0098	.0036	.0000	.0225	5.57	27.6	0.0	9.8	7.86	7.48	3.37	.038	7,200
529	" 24	Clear	.20	.0118	.0018	.0000	.0825	6.56	34.4	0.0	13.2	8.84	8.22	3.37	.022	1,125
	Av'gs,	.....	.20	.0108	.0027	.0000	.0525	6.06	31.0	0.0	11.5	8.35	7.85	3.37	.030	4,162
585	Dec. 14	V. sl'gt.	.10	.0054	.0016	.0000	.0750	7.60	32.4	...	13.2	8.17	7.48	3.16	.006	721

Etna Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrites.	Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
649	1898. Jan. 11	Clear	.05	.0058	.0020	.0000	.1200	8.10	38.0	0.0	10.4	6.20	4.81	3.88	.012	595
728	Feb. 7	Clear	.15	.0048	.0018	.0000	.1725	7.60	32.4	0.0	10.4	9.66	8.26	3.23	.008	28
802	Mar. 8	Clear	.17	.0032	.0018	.0000	.0525	6.40	28.0	0.0	8.0	8.32	7.92	2.92	.008	616
877	Apr. 5	V. sl'gt.	.17	.0048	.0018	.0000	.0450	5.32	26.0	0.0	8.0	7.20	6.40	1.72	.028	366
926	May 3	Slight	.15	.0038	.0018	.0000	.0150	4.82	21.6	0.0	3.2	7.40	6.88	1.88	.004	205
1010	" 17	Clear	.17	.0034	.0010	.0000	.0150	4.86	22.4	0.0	7.2	8.82	6.68	2.06	.006	320
1059	" 31	"	.05	.0060	.0018	.0000	.0450	4.76	19.5	0.0	5.9	8.40	6.28	1.41	.008	170
	Av'gs,	.....	.12	.0044	.0015	.0000	.0250	4.81	21.2	0.0	5.4	8.21	6.61	1.78	.006	230
1131	June 21	V. sl'gt.	.20	.0034	.0008	.0000	.0225	4.75	24.0	0.0	7.6	7.80	7.35	2.24	.006	475
1179	July 6	V. sl'gt.	.22	.0050	.0016	.0000	.0825	4.54	20.2	0.0	6.3	7.98	6.98	2.16	.006	56
1228	" 19	Clear	.20	.0062	.0014	.0000	.0600	3.94	19.4	0.0	5.4	6.20	5.71	2.47	.006	2,270
	Av'gs,	.....	.21	.0056	.0015	.0000	.0712	4.24	19.8	0.0	5.8	7.09	6.34	2.31	.006	1,160
1272	Aug. 2	Slight	.27	.0068	.0018	.0000	.0525	4.86	25.8	3.4	7.0	9.04	7.42	1.82	.018	10,850
1334	" 16	Clear	.25	.0078	.0026	.0000	.0600	5.32	27.2	0.0	10.0	11.24	9.42	2.82	.010	750
	Av'gs,	.....	.26	.0073	.0022	.0000	.0562	5.09	26.5	1.7	8.5	10.14	8.42	2.32	.014	5,800

ALLEGHENY RIVER AT MILLVALE.

Samples of the "Allegheny River at Millvale" were collected about once a week, from the middle of August to the last of October, 1897, and once in July, 1898. The supply of the borough of Millvale is obtained from the Allegheny River, about four miles below Brilliant upon the opposite side, from two cribs, one owned by the borough and one by

the Bennett Water Company. The latter is 100 feet long, 16 feet wide, and 4 feet deep, and is built of 2-inch x 4-inch lumber in the usual crate style, and covered with stone, gravel, and sand. The crib is placed in the stream, where the current is swift, and the filling has been frequently washed away, necessitating frequent repairs. The average daily pumpage is given as about 550,000 gallons. Samples were obtained to determine the efficiency of this crib, only. The river samples were collected from the bank near the pumping station, in the current of the river.

Allegheny River at Millvale.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as Albuminoid Ammonia.	Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
157	Aug. 24	Dec'd	...	.0196	.0018	.0000	.0825	1.61	10.8	...	4.0	5.57	3.98	0.89	.040	4,725
182	" 31	Slight	.40	.0156	.0014	.0000	.0775	2.19	11.6	...	4.4	4.95	4.85	1.47	.060	4,475
	Av'gs,	.....	.40	.0176	.0016	.0000	.0800	1.90	11.2	...	4.2	5.26	4.41	1.18	.050	4,600
215	Sept. 7	Slight	.30	.0166	.0022	.0000	.0375	2.19	12.4	...	5.2	5.80	4.80	1.23	.025	3,875
228	" 13	"	.25	.0204	.0074	.0000	.0600	2.80	14.0	...	6.0	9.27	6.33	1.27	.026	4,800
262	" 21	"	.25	.0146	.0046	.0000	.0525	3.19	16.4	...	7.0	7.20	5.87	1.58	.055	2,050
295	" 28	V.sl'gt	.30	.0122	.0030	.0000	.0825	2.33	15.2	...	5.6	4.21	4 04	2.78	.064	4,325
	Av'gs,	.....	.27	.0159	.0043	.0000	.0581	2.63	14.5	...	5.9	6.62	5.26	1.71	.042	3,762
325	Oct. 5	Slight	.35	0160	.0046	.0000	.0975	2.75	14.8	...	5.2	4.98	4.82	2.40	.056	12,030
357	" 12	"	.30	.0188	.0028	.0000	.0675	3.29	17.6	...	7.4	5.20	4.75	2.33	.044	23,975
383	" 19	V.sl'gt	.20	.0132	.0030	.0000	.0675	3.18	16.4	...	4.0	5 87	5.30	2.71	.028	146,000
417	" 26	V. "	.20	.0124	.0068	.0000	.0450	3.78	20.0	...	8.0	5.60	5.31	2.41	.054	94,500
	Av'gs,	.....	.26	.0151	.0043	.0000	.0694	3.25	17.2	...	6.1	5.41	5.04	2.46	.045	69,126
	1898.															
1225	July 19	0.08	.30	.0110	.0080	.0000	.0750	2.55	15.6	2.0	4.0	4.92	4.10	2.44	.016	.....

EFFLUENT—BENNETT WATER CO. CRIB, MILLVALE.

Samples of the water which had passed through this crib were collected once a week from the middle of August to December 1, 1897, and, then, about once in two weeks until the close of the experiments. These samples were collected from a tap upon the pump.

Effluent—Bennett Water Co. Crib, at Millvale.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
127	Aug. 18	Dec'd	....	.0156	.0020	.0000	.0600	1.28	13.2	3.2	5.2	6.32	4.70	1.27	.160	12,900
158	" 24	Slight	.40	.0168	.0017	.0000	.0750	1.32	10.0	...	4.4	4.70	4.08	0.65	.070	4,275
183	" 30	"	....	.0161	.0014	.0000	.0900	1.91	9.4	...	4.8	4.80	4.55	1.41	.070	5,425
	Av'gs,	.....	.40	.0162	.0017	.0000	.0750	1.50	10.9	...	4.6	5.27	4.44	1.11	.100	7,533
216	Sept. 7	Slight	.40	.0164	.0016	.0000	.0412	1.91	11.6	...	4.0	5.94	5.11	1.26	.025	3,200
229	" 13	"	.30	.0136	.0035	.0000	.0450	2.38	14.0	...	5.6	9.08	5.94	1.23	.020	9,253
263	" 21	V. "	.20	.0116	.0014	.0000	.0450	3.21	15.2	...	6.0	7.06	5.62	1.65	.046	1,000
296	" 28	V. "	.25	.0112	.0012	.0000	.0675	2.02	16.0	...	6.0	3.94	3.81	2.75	.060	3,125
	Av'gs,	.....	.29	.0132	.0019	.0000	.0497	2.38	14.2	...	5.4	6.50	5.12	1.72	.038	4,144
326	Oct. 5	V. sl'gt	.30	.0110	.0022	.0000	.0900	2.12	15.2	...	6.0	5.31	5.28	2.51	.050	6,450
358	" 12	V. "	.20	.0128	.0020	.0000	.0525	3.46	18.4	...	7.6	5.16	4.63	2.47	.048	18,725
384	" 19	V. "	.15	.0116	.0018	.0000	.0600	3.38	18.0	...	6.0	5.48	5.05	2.51	.003	71,500
416	" 26	Clear	.15	.0120	.0030	.0000	.0450	4.22	23.6	...	11.2	5.92	5.63	2.64	.030	70,000
	Av'gs,	.....	.20	.0118	.0022	.0000	.0619	3.29	18.8	...	7.7	5.47	5.15	2.53	.033	41,669
441	Nov. 2	V. sl'gt	.20	.0064	.0024	.0000	.0300	6.78	27.8	0.0	9.6	5.80	5.46	2.92	.046	79,500
477	" 8	Slight	.30	.0080	.0020	.0000	.0600	5.77	25.6	0.2	10.0	5.28	5.02	3.02	.088	23,800
495	" 16	Dec'd	.40	.0280	.0028	.0000	.0900	2.43	30.8	14.8	10.0	5.20	4.70	1.65	.340	28,300
526	" 24	V. sl'gt	.30	.0126	.0014	.0000	.0300	1.63	12.0	0.2	3.6	3.80	3.28	1.44	.084	15,100
544	" 30	Dec'd	.20	.0188	.0014	.0000	.0975	1.31	18.6	7.0	7.6	3.15	2.39	0.72	.160	39,000
	Av'gs,	.....	.28	.0148	.0020	.0000	.0615	3.58	23.0	4.4	8.2	4.65	4.17	1.95	.144	37,140
586	Dec. 14	Slight	.10	.0064	.0022	.0000	.0675	1.58	32.4	22.2	14.0	3.97	3.30	1.23	.008	7,150
614	" 28	Clear	.20	.0042	.0018	.0000	.0675	1.81	10.8	0.4	4.4	3.06	2.87	1.75	.086	3,350
	Av'gs,	.....	.15	.0053	.0020	.0000	.0675	1.69	21.6	11.3	9.2	3.51	3.08	1.49	.047	5,250

Effluent—Bennett Water Co. Crib, at Millvale.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
646	Jan. 11	Slight	.30	.0082	.0020	.0000	.1500	1.18	20.4	6.8	5.6	2.98	2.70	1.47	.142	12,000
685	" 25	V. sl'gt.	.30	.0086	.0014	.0000	.1275	0.90	8.8	0.8	2.8	2.86	2.30	0.68	.046	8,500
	Av'gs,	.....	.30	.0084	.0017	.0000	.1387	1.04	14.6	3.8	4.2	2.92	2.50	1.07	.094	10,250
729	Feb. 7	V. sl'gt	15	.0062	.0026	.0000	.1575	1.51	10.0	0.0	5.2	4.08	3.62	1.72	.046	.....
767	" 22	Slight	.20	.0038	.0022	.0000	...	1.28	10.3	0.3	3.2	3.12	2.20	1.14	.032	12,950
	Av'gs,	.....	.17	.0050	.0024	.0000	.1575	1.39	10.1	0.1	4.2	3.60	2.91	1.43	.039	12,950
803	Mar. 8	Clear	.20	.0046	.0020	.0000	.0525	1.44	10.0	0.0	3.6	4.68	3.01	1.27	.050	5,100
838	" 22	Mud'y	.25	.0140	.0018	.0000	.0525	0.82	26.8	15.6	5.6	3.24	2.40	...	.162	.....
	Av'gs,	.....	.22	.0093	.0019	.0000	.0525	1.13	18.4	7.8	4.6	3.96	2.70	1.27	.106	5,100
878	Apr. 5	V. sl'gt.	.17	.0068	.0012	.0000	.0450	1.40	8.8	0.0	2.8	2.88	2.14	0.27	.058	3,400
913	" 19	V. "	.22	.0056	.0018	.0000	.0375	1.38	9.0	0.2	3.2	2.77	2.58	0.92	.045	3,850
	Av'gs,	.....	.19	.0062	.0015	.0000	.0412	1.39	8.9	0.1	3.0	2.82	2.36	0.59	.051	3,625
1011	May 17	Mud'y	.40	.0310	.0026	.0000	.0150	1.05	55.6	45.3	4.0	3.52	2.70	1.16	.046	53,200
1054	" 31	V. sl'gt.	.27	.0068	.0008	.0000	.0450	2.04	9.4	0.0	3.4	2.92	2.70	0.82	.038	2,400
	Av'gs,	.....	.33	.0189	.0017	.0000	.0300	1.54	32.5	22.6	3.7	3.22	2.70	0.99	.042	27,800
1181	July 6	Slight	.27	.0110	.0016	.0000	.0750	1.42	9.4	0.8	3.8	3.35	3.10	0.92	.020	12,500
1274	Aug. 2	Slight	25	.0094	.0016	.0000	.0450	2.79	23.2	8.4	5.0	5.85	4.72	1.34	.014	18,200
1335	" 16	"	.30	.0120	.0022	.0000	.0600	1.92	11.6	2.4	2.6	3.54	3.20	1.61	.006	19,500
	Av'gs,	.....	.27	.0107	.0019	.0000	.0525	2.35	17.4	5.4	3.8	4.69	3.96	1.47	.010	18,800

MILLVALE TAP.

Samples of the "Tap Water" supplied by the Bennett Water Company in Millvale were collected about once a month during the work. The water is pumped directly into the service system, the surplus passing into an elevated tank. The collections were made from a tap near the railroad station.

Millvale Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
106	Aug. 11	Dec'd	....	.0205	.0025	.0000	.0740	1.97	22.6	11.2	6.2	6.10	7.10	0.69	.250	142
327	Oct. 5	V.sl'gt	.30	.0098	.0012	.0000	.0975	2.68	15.2	...	4 8	5.30	5.17	2.58	.056	2,301
385	" 19	V. "	.15	0098	.0012	.0000	.0600	3.42	17.6	...	7.6	5.31	4.84	2.64	.003	9,120
	Av'gs,	.....	.22	.0098	.0012	.0000	.0787	3.05	16.4	...	6.2	5.30	5.00	2.61	.029	5,710
442	Nov. 2	V.sl'gt	.20	.0108	.0016	.0000	.0225	6.80	28.0	0.0	10.8	5.82	5.48	2.06	.054	2,640
496	" 16	Dec'd	.40	.0276	.0026	.0000	.0750	2.32	44.4	26.0	7.2	5.61	4.85	1.51	.564	16,625
545	" 30	.....	.20	.0146	.0012	.0000	.1050	1.66	14.2	0 2	5.2	3.48	3.14	0.97	.092	9,500
	Av'gs,	.....	.27	.0177	.0018	.0000	.0675	3.59	28.9	8.7	7.7	4.97	4.49	1.51	.237	9,588
615	Dec. 28	V.sl'gt	.20	.0054	.0020	.0000	.0750	2.58	10.8	0.2	4.4	2.67	2.24	1.78	.080	3,125
	1898.															
686	Jan. 26	V.sl'gt	.30	.0094	.0012	.0000	.1200	0.97	13.6	5.6	3.6	2.48	2.17	0.65	.050	5,820
768	Feb. 22	Slight	.20	.0044	.0024	.0000	...	1.61	10.4	0.4	3.2	3.32	2.26	0.96	.030	9,850
839	Mar. 22	Mud'y	.25	.0148	.0020	.0000	.0600	0.94	24.4	11.2	5.6	3.28	2.35	0.99	.100	.....
914	Apr. 19	V.sl'gt	.17	.0044	.0020	.0000	.0375	1.29	10.0	0.0	4.0	3.08	2.70	0.92	.050	2,775
1055	May 31	V.sl'gt	.36	.0078	.0010	.0000	.0450	1.15	9.1	0.0	3.8	2.80	2.55	0.79	.028	1,870

Millvale Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
1182	July 6	Slight	.30	.0118	.0028	.0000	.0900	1.72	9.6	1.0	4.1	3.48	3.35	0.96	.016	7,600
1275	Aug. 2	Slight	.27	.0088	.0016	.0000	.0600	2 66	16 6	1.6	4.6	5.88	4.70	1.50	016	30,100
1336	" 16	"	.30	.0120	.0026	.0000	.0600	1.88	11.6	2.2	2.6	3 50	3.08	1.16	.008	6,500
	Av'gs,	.....	.28	.0104	.0021	.0000	.0600	2.27	14.1	1.9	3.6	4.69	3.89	1.33	.012	18,300

OHIO RIVER AT SEWICKLEY.

Samples were collected of the "Ohio River at Sewickley," three times in the latter part of 1897 and once in June, 1898.

The water supply of Sewickley is derived, during a portion of the year, when the water-shed will not furnish sufficient water, from cribs in the Ohio River near Osborne Station. There are two cribs, one built in 1893, which is 32 feet long and 16 feet wide, and another, built in 1894, which is 80 feet long and 16 feet wide. Both are of the usual crate construction with stone, gravel, and sand above and around them. The samples were collected out over the crib from a boat.

Ohio River at Sewickley.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
445	Nov. 3	Slight	.15	.0110	.0016	.0000	.0750	5.36	31.8	0.2	13.0	6.13	4.20	5.33	.046	23,400
512	" 22	"	.30	.0210	.0024	.0000	.0525	2.02	28.4	15.2	9.6	4.14	2.60	1.34	.150	54,000
	Av'gs,	.....	.22	.0160	.0020	.0000	.0637	3.69	30.1	7.7	11.3	5.13	3.40	3.33	.098	38,700

Ohio River at Sewickley.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1898.															
577	Dec. 14	Slight	.25	.0086	.0020	.0000	.0600	2.27	13.2	0.4	5.6	3.21	2.72	1.16	.058	37,400
1152	June 27	Slight	.20	.0138	.0046	.0000	.0525	2.40	19.6	6.6	4.2	4.02	3.23	1.54	.014	15,500

EFFLUENT—SEWICKLEY CRIB.

Samples were collected from the "Effluent" from this crib, twice in November, 1897, and once in June, 1898. The samples were taken from a tap near the pump.

Effluent—Sewickley Crib.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
446	Nov. 3	Clear	.10	.0325	.0018	.0000	.1500	3.74	32.0	0.0	13.6	13.32	12.78	2.44	.004	910
513	" 22	Slight	.20	.0080	.0014	.0000	.0600	2.34	18.4	0.0	5.2	5.70	5.27	1.89	.028	9,500
	Av'gs,	.....	.15	.0202	.0016	.0000	.1050	3.04	25.2	0.0	9.4	9.51	9.02	2.16	.016	5,205
	1898.															
1153	June 27	Slight	.22	.0140	.0040	.0000	.0600	2.78	18.2	1.6	5.4	6.77	6.42	1.61	.012	14,100

SEWICKLEY TAP.

Samples were collected near the railroad station in Sewickley, of the "Tap Water" twice in November and once in December, 1897.

Sewickley Tap.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as.				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
447	Nov. 3	Clear	.05	.0160	.0010	.0000	.1875	3.73	28.0	0.0	11.6	13.01	12.22	1.82	.004	994
514	" 22	Slight	.20	.0098	.0010	.0000	.0825	2.83	23.6	0.0	7.5	8.76	8.00	2.68	.014	5,850
	Av'gs,	.....	.12	.0129	.0010	.0000	.1350	3.28	25.8	0.0	9.5	10.88	10.11	2.25	.009	3,422
578	Dec. 14	Slight	.20	.0058	.0016	.0000	.0525	4.48	19.6	. ..	8.8	8.26	7.28	2.13	.058	430

TAP IN DEPARTMENT OF PUBLIC SAFETY BUILDING, BEFORE FILTRATION.

Samples were collected from a tap in this building, once a week from September to the last of November, 1897, and once during the months of December, 1897, and January and March, 1898. The water supply for the building is passed through a pressure filter, in which sulphate of alumina is added. These samples were collected from a special tap delivering water which had not passed through the filter.

Tap in Department of Public Safety Building, before Filtration.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
270	Sept. 22	Slight	.40	.0130	.0022	.0000	.0525	3.08	15.2	...	4.4	5.47	5.48	1.68	.044	182
280	" 27	"	.35	.0104	.0010	.0000	.0750	3.38	16.8	...	5.6	5.56	4.79	2.58	.036	4,620
	Av'gs,	.....	.37	.0117	.0016	.0000	.0637	3.23	16.0	...	5.0	5.51	5.13	2.13	.040	2,401

Tap in Department of Public Safety Building, before Filtration.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
314	Oct. 4	V. sl'gt.	.30	.0158	.0008	.0000	.0900	2.59	16.6	...	8.0	5.70	4.61	3.02	.064	10,192
340	" 11	V. "	.30	.0132	.0016	.0000	.0750	3.19	16.0	...	5.6	5.81	4.15	2.78	.036	1,134
371	" 18	V. "	.20	.0148	.0018	.0000	.0675	3.51	16.4	...	7.2	5.12	4.87	2.16	.018	800
401	" 25	V. "	.25	.0218	.0024	.0000	.0488	3.48	16.8	...	4.4	5.20	5.01	2.47	.046	34,760
	Av'gs,	.....	.26	.0164	.0016	.0000	.0703	3.19	16.4	...	6.3	5.46	4.66	2.61	.041	11,721
430	Nov. 1	V. sl'gt.	.20	.0110	.0038	.0000	.0525	4.02	17.6	0.1	7.2	5.80	5.68	2.88	.042	58,100
462	" 8	Slight	.25	.0116	.0012	.0000	.0325	6.41	21.5	0.0	8.4	4.68	4.41	3.68	.055	18,325
510	" 22	.....	.30	.0120	.0008	.0000	.0525	2.09	14.4	0.8	4.2	2.84	2.50	1.68	.070	24,150
	Av'gs,	.....	.25	.0115	.0019	.0000	.0458	4.17	17.8	0.3	6.6	4.44	4.20	2.75	.056	33,525
591	Dec. 20	Slight	.30	.0078	.0018	.0000	.0675	1.61	13.6	2.8	4.0	2.04	1.68	1.44	.068	.....
	1898.															
661	Jan. 17	Slight	.30	.0090	.0018	.0000	.0975	1.10	14.4	4.0	5.2	1.52	1.21	1.30	.090	26,250
810	Mar. 14	Slight	.25	.0060	.0012	.0000	.0450	1.36	8.4	0.4	2.4	3.10	2.27	1.23	.024	13,100

TAP IN DEPARTMENT OF PUBLIC SAFETY BUILDING,

AFTER FILTRATION.

Samples were collected from a tap in the basement, supplied with filtered water, on the same days that samples were collected of the unfiltered water in the building.

Tap in Department of Public Safety Building, after Filtration.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
271	Sept. 22	Clear	.10	.0116	.0030	.0000	.0338	2.82	15.4	...	5.2	6.14	5.29	1.89	.004	148
281	" 27	Slight	.20	.0082	.0014	.0000	.0825	3.11	15.0	...	4.6	5.64	4.86	2.64	.002	640
	Av'gs,	.....	.15	.0099	.0022	.0000	.0581	2.96	15.2	...	4.9	5.89	5.07	2.26	.003	394
315	Oct. 4	Clear	.20	.0110	.0012	.0000	.0750	2.72	17.2	...	8.4	6.70	4.66	3.02	.030	416
341	" 11	"	.20	.0110	.0018	.0000	.0450	2.91	16.4	...	5.6	4.77	4.11	2.40	.004	164
372	" 18	"	.10	.0136	.0016	.0000	.0600	3.29	16.0	...	6 8	5.03	4.68	2.67	.005	370
402	" 25	"	.10	.0210	0024	.0000	.0450	3.30	16.8	...	4.0	5.30	5.04	2.37	.018	9,540
	Av'gs,	.....	.15	.0141	.0017	.0000	.0562	3.05	16.6	...	6.2	5.45	4.62	2.61	.014	2,622
431	Nov. 1	Clear	.10	.0112	.0040	.0000	.0600	3.68	18.4	0.0	6.4	6.49	6.11	2.36	.004	413
463	" 8	"	.15	.0110	.0014	.0000	.0525	4.05	21.6	0 0	8.8	5.30	4.98	4.02	.006	1,106
511	" 22	"	.10	.0126	.0006	.0000	.0825	1.93	11.6	0.0	2.0	2.78	2.22	1.34	.030	1,260
	Av'gs,	.....	.12	.0116	.0020	.0000	.0650	3.22	17.2	0.0	5.7	4.86	4.44	2.57	013	926
592	Dec. 20	Slight	.20	0062	.0018	.0000	.0750	1.34	10.6	0.0	5.0	1.87	1.43	1.23	.068	.....
	1898.															
662	Jan. 17	Slight	.20	.0086	.0022	.0000	.1050	1.22	10.8	0.6	4.0	1.60	1.17	1.30	.010	9,300
811	Mar. 14	V.sl'gt	.17	.0054	.0012	.0000	.0525	1.34	8.0	0.0	2.4	3.21	2.16	1.34	.018	910

WATER IN EXPERIMENTAL BOILERS.

Samples of the water being evaporated in the experimental boilers were collected, about once a week during the months of June, July, and August, 1898. (See Chapter VI., Page 216.)

Water from Experimental Boilers.

(PARTS PER 100,000.)

Serial Number.	Number of Boiler.	Date of Collection.	Temperature. Degrees F.	Color.	Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.
						Total.	Suspended.	Loss on Ignition.				
1072	2	June 6	189	0.20	2.35	9.6	0.8	2.4	3.14	1.80	2.06	.006
1073	3	" 6	158	0.20	2.32	9.4	1.0	2.4	3.55	3.08	0.85	.030
1095	1	" 13	205	0.30	30.54	98.9	2.0	14.8	14.80	5.05	15.34	.001
1096	2	" 13	201	0.30	5.84	21.9	1.1	5.4	3.30	2.80	3.50	.009
1097	3	" 13	129	0.27	4.10	21.2	4.6	4.8	3.80	3.72	2.06	.018
1101	1	" 14	100	0.20	26.52	103.8	0.8	17.8	17.80	4.95	23.53	.010
1102	2	" 14	106	0.30	24.22	103.6	0.4	17.7	18.33	4.90	21.18	.008
1103	3	" 14	100	0.27	25.43	102.0	0.4	18.0	19.10	6.10	20.26	.008
1233	3	" 19	..	3.00	46.10	.....	...	24.5	32.20	8.46	18.81	.001
1116	1	" 20	210	0.40	16.50	87.8	4.0	15.4	23.94	4.50	22.80	.002
1117	2	" 20	208	0.70	5.00	33.2	5.0	6.4	10.13	3.18	7.18	.004
1118	3	" 20	208	0.65	17.22	108.6	17.4	21.1	24.97	6.62	20.60	.002
1148	1	" 27	194	1.00	48.84	156.2	4.2	20.4	28.32	7.20	16.49	.002
1149	2	" 27	210	0.28	18.09	63.2	8.0	9.6	12.00	3.78	7.51	.008
1150	3	" 27	208	2.80	43.11	169.2	34.0	26.4	25.48	9.09	12.96	.003
1232	3	" 28	...	2.10	20.40	.....	...	26.2	28.40	15.10	17.69	.004
1171	1	July 5	208	0.80	72.10	206.8	7.2	30.0	14.60	10.20	21.94	.001
1172	2	" 5	208	0.65	46.85	140.9	10.2	15.4	20.32	6.00	18.36	.001
1173	3	" 5	208	2.80	17.58	92.4	14.8	15.6	22.98	7.96	12.99	.001
1195	1	" 11	210	1.90	86.94	218.9	3.3	33.8	54.08	10.38	16.39	.001
1196	2	" 11	208	2.00	83.30	197.2	2.2	24.2	31.52	9.18	17.99	.001
1197	3	" 11	208	3.10	29.90	103.7	12.1	20.0	26.00	8.90	10.95	.002
1217	1	" 18	205	0.90	21.20	65.7	1.9	12.0	14.70	5.50	7.32	.010
1218	2	" 18	210	1.20	132.70	282.2	12.4	27.0	30.30	8.70	18.47	.001
1219	3	" 18	210	2.10	119.00	258.6	1.2	31.0	35.90	9.12	17.37	.001
1244	1	" 25	210	1.40	182.50	390.2	1.4	35.6	16.00	9.00	17.91	.001
1245	2	" 25	208	1.25	187.06	388.0	2.8	37.4	35.70	8.36	20.60	.001
1246	3	" 25	210	0.90	34.40	169.9	2.7	20.4	29.72	8.00	18.99	.001
1263	1	Aug. 1	210	2.40	195.68	586.4	5.2	65.8	46.42	8.20	17.17	.001
1264	2	" 1	210	2.20	248.86	524.4	11.2	60.2	40.40	9.32	20.98	.001
1265	3	" 1	210	3.10	143.44	328.6	6.6	24.6	43.20	9.30	18.61	.001
1295	1	" 8	210	1.90	164.88	.....	...	29.6	48.60	7.12	17.14	.001
1296	2	" 8	210	2.10	212.20	.....	...	34.0	39.44	8.10	15.78	.001
1297	3	" 8	210	3.80	218.60	.....	...	55.2	36.82	13.48	18.09	.001
1304	1	" 10	...	2.10	136.25	.....	...	31.2	43.88	4.05	24.30	.001
1305	2	" 10	...	2.80	238.50	.....	...	67.4	15.08	5.12	29.07	.001
1306	3	" 10	...	3.60	118.00	.....	...	33.2	17.50	11.61	15.41	.001
1323	1	" 15	210	1.00	30.08	.....	...	18.8	30.16	6.96	14.35	.001
1324	2	" 15	210	0.90	41.12	.....	...	15.8	25.28	5.34	14.41	.001
1325	3	" 15	210	1.90	30.04	.....	...	20.0	28.16	7.10	13.50	.001
1356	1	" 22	210	1.40	70.40	.....	...	22.0	38.80	8.84	15.83	.002
1357	2	" 22	210	1.10	57.04	.....	...	20.0	23.36	5.10	11.64	.002
1358	3	" 22	210	14.00	58.20	.....	...	49.4	49.40	14.60	19.67	.002
1368	1	" 25	...	1.60	58.96	.....	...	18.0	51.20	6.74	32.17	.001
1369	2	" 25	...	1.30	72.80	.....	...	18.4	59.24	6.60	41.23	.001
1370	3	" 25	...	2.00	53.28	.....	...	25.7	51.32	12.40	18.95	.001
1386	1	" 29	212	0.70	11.92	.....	...	11.2	18.42	5.60	6.92	.001
1387	2	" 29	212	0.60	10.30	.....	...	7.8	14.20	4.00	9.11	.001
1388	3	" 29	212	2.00	5.32	.....	...	8.4	11.18	4.68	4.29	.001

DRIVEN WELL AT BRILLIANT.

Samples from the "Driven Well" at Brilliant were collected during May and June, 1897. (See Appendix No. 5, Page 360.)

Driven Well at Brilliant.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as Albuminoid Ammonia.	Nitrogen as Free Ammonia.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Chlorine.	Residue on Evaporation. Total.	Residue on Evaporation. Suspended.	Residue on Evaporation. Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Depth of Well in Feet.
	1897.															
1	May 24	Mud'y	...	...	...	...	...	...	29.4	...	11.8	17.7	...	2.6	Tr.	42
2	" 26	"	...	.0120	.0093	...	...	4.8	34.0	...	9.2	15.0	...	1.3	.000	54
3	" 28	.....	...	.0030	.0027	...	...	5.7	34.8	...	7.3	17.2	...	0.3	.000	63
4	" 31	.....	...	.0050	.0066	...	...	11.0	41.0	...	9.4	14.5	...	0.1	.000	80
	Av'gs,	.....	...	.0067	.0062	...	...	7.2	34.8	...	9.4	16.1	...	1.1	.000	.....
9	June 9	Dec'd	...	.0020	.0850	...	...	117.8	235.0	...	28.4	32.0	...	...	...	121
10	" 10	.....	...	.0030	.1060	...	...	173.6	349.6	...	27.6	38.7	...	0.0	.000	143
	Av'gs,	.....	...	.0025	.0955	...	...	145.7	292.8	...	28.0	35.3	...	0.0	.000	.....

HOWE SPRING.

Samples of water from this well-known spring, which is used largely by householders in the East End, were collected frequently during the months of August, September, and October, 1897, and once in May, 1898.

Howe Spring.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
	1897.															
87	Aug. 5	Clear	...	.0026	Tr.	.0001	1.0375	1.79	38.3	..	18.3	19.06	47.78	1.67	.008	...
108	" 12	"	...	.0040	.0009	.0000	1.2580	1.77	36.8	...	19.0	17.27	47.55	1.68	.016	...
122	" 18	"	...	.0018	.0016	.0000	1.3125	1.75	40.4	...	10.6	30.05	28.92	1.53	.008	* 74
	Av'gs,	.....	...	.0028	.0012	.0000	1.2027	1.77	38.5	...	16.0	22.13	41.42	1.63	.011	...
199	Sept. 3	Clear	.00	.0036	.0009	.0000	1.8000	1.86	38.8	...	20.0	16.78	28.62	1.96	.008	...
231	" 13	"	.00	.0056	.0016	.0000	1.5750	1.75	39.4	...	18.4	24.90	28.87	1.23	.002	16
286	" 27	"	.00	.0052	.0010	.0000	1.5375	2.15	38.8	...	18.4	25.70	27.83	1.41	.014	76
	Av'gs,	.....	.00	.0048	.0012	.0000	1.6375	1.92	39.0	...	18.9	22.46	28.44	1.53	.008	46
399	Oct. 25	Clear	.00	.0048	.0024	.0000	1.2375	1.90	39.2	...	18.2	24.12	23.11	0.92	.010	6,640
	1898.															
1006	May 18	Clear	.10	.0018	.0004	.0000	0.0150	2.50	41.0	0.0	15.0	28.05	23.98	1.88	.004	270

* Collected August 25, 1897.

WELL AT McCONWAY-TORLEY MANUFACTURING CO.

Samples were collected, twice in November and once in December, 1897, of the water obtained at this well; in order to ascertain the character of the ground water to be found in this vicinity, along the bank of the Allegheny River. The well is cased, is six feet in diameter and forty-five feet deep. The samples were collected from a tap near the pump.

Well at McConway-Torley Manufacturing Co.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
450	Nov. 3	Clear	.15	.0124	.0018	.0000	.1500	3.01	32.0	0.2	12.8	16.03	15.20	2.23	.002	...
516	" 22	Slight	.10	...	...	.0000	...	3.18	28.0	0.0	10.4	14.80	13.13	2.13	.002	494
	Av'gs,	.....	.12	.0124	.0018	.0000	.1500	3.09	30.0	0.1	11.6	15.41	14.16	2.18	.002	494
564	Dec. 7	Clear	.00	.0068	.0026	.0000	...	3.16	28.8	0.0	10.4	15.61	14.04	1.89	.004	...

WELL AT SLIGO MILLS.

Samples of the water, obtained from a well located at this mill, were collected occasionally during July and August, 1897, and in June, 1898.

Well at Sligo Mills.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1897.															
58	July 18	Slight	...	.0110	.0230	.0040	.0000	1.84	30.6	0.6	8.9	14.49	30.00	4.71	.140	.....
88	Aug. 5	V.sl'gt	...	.0056	.0046	.0025	.4559	2.85	58.4	...	12.9	24.04	45.51	15.15	.040	.....
	1898.															
1081	June 13	Clear	.05	.0036	.0008	.0010	.0225	7.80	84.5	0.0	23.4	43.80	23.20	25.90	.001	2,300

MISCELLANEOUS CITY SAMPLES.

The following samples were collected during September, 1897, from various wells, springs, and taps in the 21st Ward, at the time when typhoid fever was abundant.

Miscellaneous City Samples,—Twenty-first Ward.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
Tap on Frankstown Avenue.																
166	1897. Aug. 28	V. sl'gt.	.60	.0180	.0018	.0000	.1050	1.85	9.2	...	3.2	4.92	3.24	1.13	.060	...
Tap on Larimer Avenue.																
187	Sept. 1	Slight	.40	.0126	.0009	.0000	.0675	1.87	11.2	...	4.4	4.70	4.43	1.13	.018	346
Tap on Thompson Street.																
188	Sept. 1	Clear	.30	.0144	.0012	.0000	.1500	1.72	10.4	...	4.4	4.45	4.45	1.43	.018	130
Dairy—Well Water.																
189	Sept. 1	Clear	.00	.0034	.0007	.0000	1.1250	2.05	33.6	...	8.0	14.24	28.30	2.95	.010	1,500
Larimer Avenue Spring.																
195	Sept. 2	Dec'd	.30	.0220	.0069	.0001	4.5000	3.25	42.2	20.2	12.4	5.68	4.08	1.96	.208	14,700
Negley Run Spring.																
203	Sept. 6	Clear	.10	.0107	.0042	.0000	3.0000	3.29	31.0	...	20.8	9.94	5.55	2.02	.004	3,000
Tap on Shetland Avenue.																
204	Sept. 6	Clear	.20	.0060	.0018	.0000	4.1250	5.06	48.4	...	32.6	13.35	6.29	2.61	.014	1,000
Dairy—Spring Water.																
205	Sept. 6	Dec'd	.45	.0078	.0018	.0000	2.6250	1.95	31.2	...	18.4	10.85	12.87	1.23	.019	1,848

MISCELLANEOUS SUBURBAN SAMPLES.

The following samples were collected at various times of certain wells, springs, and streams, at the time of a typhoid fever epidemic in Turtle Creek. Also a few samples at Kittanning, when typhoid was unusually prevalent there.

Miscellaneous Suburban Samples.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
Seger's Well at Turtle Creek.																
139	1897. Aug. 20	V. sl'gt	...	.0085	.0020	.0000	1.3500	2.56	36.8	...	17.4	14.42	11.68	4.20	.120	1,650
Knabe Well at Turtle Creek.																
140	Aug. 20	Clear	....	.0185	.0075	.0000	.0000	6.29	71.8	...	37.0	18.37	11.84	7.98	.016	3,800
Glunt Spring at Turtle Creek.																
141	Aug. 20	Clear	...	.0155	.0019	.0000	...	0.90	46.4	1.6	12.4	21.98	23.10	7.32	.100	1,400
Thompson's Run at Turtle Creek.																
197	Sept. 2	.....	.40	.1040	.0012	.0000	.1575	1.36	140.0	6.4	39.0	...	2.92	62.76	.284	3,825
Turtle Creek at Turtle Creek.																
136	Aug. 20	Dec'd	...	.1216	.0016	.0001	.3750	2.35	129.4	4.6	26.0	...	0.80	61.75	.060	896
138	" 20	Slight	...	.0916	.0018	.0000	.3000	2.45	134.0	1.6	24.4	...	0.87	67.18	.075	353
198	Sept. 2	Dec'd	.40	.0980	.0016	.0000	.1650	2.24	114.8	0.4	18.4	3.04	0.62	56.62	.102	28,000
Monongahela River at Mouth of Turtle Creek,																
137	Aug. 20	Dec'd	...	.0290	.0069	.0000	.3188	0.45	15.2	5.8	2.4	6.02	1.60	3.23	.400	2,925
196	Sept. 2	Slight	.15	.0144	.0048	.0000	.1500	0.79	14.8	...	3.2	7.05	1.38	3.40	.040	5,225
Monongahela River at Mouth of Beck's Run.																
185	Sept. 1	Slight	.45	.0146	.0109	.0000	.0900	0.75	11.6	2.4	2.0	4.54	1.53	3.88	.060	23,250

Miscellaneous Suburban Samples—Continued.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
Allegheny River at Kittanning.																
711	1898. Feb. 4	Slight	.30	.0110	.0016	.0000	.1500	1.38	8.8	0.2	2.8	3.42	2.46	0.82	.164	.....
Reservoir in Kittanning.																
712	Feb. 3	Slight	.30	.0098	.0020	.0000	.1575	2.20	8.8	0.0	1.6	3.16	2.10	1.96	.056	2,100
Tap in Kittanning.																
713	Feb. 3	Slight	.25	.0096	.0024	.0000	.1650	1.84	9.6	0.3	3.2	3.82	2.30	3.23	.034	3,050

INDIAN CREEK AND VICINITY.

Samples were collected, during the autumn of 1898, from Indian Creek, and some of its tributaries; from the Youghiogheny River, and from some of its tributaries, in the vicinity of Indian Creek.

Indian Creek.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
1203	1898. July 13	V.sl'gt.	.10	...	...	...	...	0.38	4.2	0.0	1.8	2.96	2.86	0.24	.006	450
1220	" 18	Slight	.17	.0088	.0016	.0000	.0600	0.42	10.2	5.1	1.7	2.28	2.04	0.17	.034	...
	Av'gs,	.....	.13	.0088	.0016	.0000	.0600	0.40	7.2	2.5	1.7	2.62	2.45	0.20	.020	450

Indian Creek.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as, Albuminoid Ammonia.	Nitrogen as, Free Ammonia.	Nitrogen as, Nitrites.	Nitrogen as, Nitrates.	Chlorine.	Residue on Evaporation, Total.	Residue on Evaporation, Suspended.	Residue on Evaporation, Loss on Ignition.	Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
	1898.															
1268	Aug. 1	Clear	.10	.0070	.0022	.0000	.0525	0.94	4.1	1.1	0.6	1.58	2.28	0.06	.016	...
1330	" 15	Dec'd	.15	.0220	.0022	.0000	.0525	0.70	16.6	10.6	2.2	1.80	1.82	0.41	.012	.....
1353	" 19	1.50	.30	.0410	.0032	.0000	.0225	0.50	78.0	71.6	1.9	0.78	0.80	0.58	.004	3,300
1371	" 25	Dec'd	.30	.0080	.0012	.0000	.0150	0.40	13.4	6.0	2.0	1.22	1.20	0.08	.006	.....
1389	" 31	Clear	.10	.0042	.0016	.0000	.0150	0.70	3.2	0.0	1.2	2.28	2.22	0.04	.010	.....
	Av'gs,	.....	.19	.0164	.0021	.0000	.0315	0.65	23.1	17.9	1.6	1.53	1.66	0.23	.010	3,300
1392	Sept. 1	V.sl'gt	.10	.0040	.0010	.0000	.0075	0.48	3.5	0.0	1.6	1.78	1.74	0.00	.014	1,350
1395	" 5	Slight	.20	.0042	.0038	.0000	.0750	0.44	3.8	0.2	1.2	1.94	1.92	0.00	.001	.....
1401	" 12	V.sl'gt	.10	.0048	.0050	.0000	.0525	0.45	3.4	0.0	1.2	1.98	1.90	0.00	.001	.....
1405	" 18	Clear	.10	.0054	.0044	.0000	.0525	0.30	3.3	0.0	0.8	2.08	2.00	0.00	.001	.....
1416	" 26	"	.10	.0074	.0088	.0000	.0750	0.42	3.0	0.0	1.2	2.00	1.90	0.00	.001	.....
	Av'gs,	.....	.12	.0052	.0046	.0000	.0525	0.42	3.4	0.0	1.2	1.96	1.89	0.00	.004	1,350

Mill Run.

1204	July 13	Clear	.20	...	...	...	...	0.32	4.0	0.0	1.8	2.90	2.65	0.00	.004	13,600
1221	" 18	Dec'd	.27	.0190	.0014	.0000	.0600	0.32	100.2	94.2	2.4	2.34	2.10	0.19	.026	.....
	Av'gs,	.....	.23	.0190	.0014	.0000	.0600	0.32	52.1	47.1	2.1	2.62	2.37	0.09	.015	13,600
1269	Aug. 1	Slight	.20	.0072	.0024	.0000	.0600	1.03	5.4	1.8	0.8	2.14	3.10	0.06	.014	.....
1331	" 15	"	.25	.0140	.0014	.0000	.0600	0.58	6.0	1.6	1.8	1.68	1.60	0.08	.008	.....
1354	" 19	1.80	.30	.0380	.0034	.0000	.0300	0.40	87.2	79.6	3.0	1.48	1.40	0.34	.006	3,980
1372	" 25	Slight	.20	.0068	.0008	.0000	.0225	0.42	7.4	0.5	2.2	1.70	1.62	0.04	.010	.....
1390	" 31	Clear	.17	.0038	.0016	.0000	.0150	0.58	3.6	0.0	2.0	2.20	2.20	0.02	.012	.....
	Av'gs,	.....	.22	.0140	.0019	.0000	.0375	0.60	21.9	16.7	2.0	1.84	1.98	0.11	.010	3,980

Mill Run.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
1393	Sept. 1	V. sl'gt.	.17	.0034	.0016	.0000	.0150	0.52	3.4	0.0	1.4	2.00	1.90	0.00	.010	1,200
1396	" 5	Slight	.27	.0054	.0036	.0000	.0675	0.46	3.7	0.4	1.6	2.10	2.12	0.00	.001	.....
1402	" 12	Clear	.20	.0040	.0050	.0000	.0675	0.62	3.2	0.0	1.4	2.32	2.20	0.00	.001	.....
1406	" 19	"	.20	.0060	.0050	.0000	.0675	0.30	3.8	0.0	1.0	2.30	2.28	0.00	.001	.....
1407	" 19	"	.10	.0058	.0062	.0000	.0750	0.28	2.6	0.0	0.8	0.80	0.78	0.00	.000	1,175
1414	" 25	"	.10	.0028	.0060	.0000	.0675	0.42	2.4	0.0	1.2	0.44	0.40	0.00	.001	.....
1415	" 26	"	.20	.0058	.0054	.0000	.0750	0.40	4.4	0.0	2.0	2.56	2.48	0.00	.001	.....
	Av'gs,	.....	.18	.0047	.0047	.0000	.0621	0.43	3.4	0.1	1.3	1.79	1.74	0.00	.002	1,190

Spring at Head of Pike Run.

1355	1898. Aug. 20	Clear	.10	.0100	.0030	.0000	.0225	0.42	2.0	0.0	0.5	0.80	0.82	0.04	.002	385

Resler's Run.

1394	Sept. 1	V. sl'gt.	.12	.0030	.0008	.0000	.0180	0.60	2.8	0.0	1.6	0.90	0.84	0.00	.008	650

Laurel Hill Creek.

1400	Sept. 12	Clear	.20	.0060	.0032	.0000	.0525	0.60	3.8	0.0	2.0	2.00	1.90	0.00	.001	...
1408	" 18	"	.20	.0062	.0038	.0000	.0750	0.30	3.6	0.0	1.1	2.38	2.40	0.00	.001	...
1411	" 26	"	.10	.0072	.0048	.0000	.0750	0.28	3.0	0.0	1.2	1.98	1.90	0.00	.001	...
	Av'gs,	.....	.17	.0065	.0039	.0000	.0675	0.39	3.5	0.0	1.4	2.12	2.07	0.00	.001	...

Castleman's River.

1399	Sept. 12	Clear	.20	.0068	.0032	.0000	.0750	0.60	5.7	0.0	2.0	1.34	1.30	1.54	.001	...
1409	" 18	"	.10	.0070	.0078	.0000	.0750	0.50	9.8	0.0	4.6	2.88	1.92	2.51	.001	...
1413	" 26	"	.20	.0070	.0054	.0000	.0750	0.28	9.6	0.0	3.2	4.86	1.38	3.13	.001	...
	Av'gs,	.....	.17	.0069	.0055	.0000	.0750	0.46	8.4	0.0	3.3	3.03	1.53	2.39	.001	...

Youghiogheny River.

(PARTS PER 100,000.)

Serial Number.	Date of Collection.	Turbidity.	Color.	Nitrogen as,				Chlorine.	Residue on Evaporation.			Total Hardness.	Alkalinity.	Sulphuric Acid.	Iron.	Bacteria Per Cubic Centimeter.
				Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.		Total.	Suspended.	Loss on Ignition.					
1410	Sept. 18	Clear	.10	.0088	.0064	.0000	.0975	0.41	5.2	0.0	2.0	2.12	2.08	0.00	.091	...
1412	" 26	V. sl'gt.	.20	.0168	.0060	.0000	.0975	0.30	2.8	0.0	1.6	1.48	1.45	0.00	.001	...
	Av'gs,	.....	.15	.0128	.0062	.0000	.0975	0.35	4.0	0.0	1.8	1.80	1.76	0.00	.001	...

REPORT

UPON

Bacteriological Investigations

OF

Fifteen Samples of Pittsburgh City Water,

BY

EUGENE WASDIN, M. D.

Past Assistant Surgeon, United States Marine Hospital Service.

APPENDIX No. 3.

APPENDIX No. 3.

MR. MORRIS KNOWLES,
Resident Engineer,
Pittsburgh Filtration Commission.

SIR:—

I beg to report that acting in deference to the wishes of Chancellor W. J. Holland, Chairman of the Committee on Water Analysis, I started, on the 19th of March last, to analyze samples of the water supplied to the city, for the purpose of isolating any bacteria that might be injurious to health; or which would tend, by their presence in this water, to show that the city water supply is much polluted, and that upon this pollution depends much of the prevailing typhoid fever.

By courtesy I have worked in the bacteriological laboratory of the Bureau of Health, and wish to express my gratification and thanks for the many and graceful courtesies received at the hands of those officials with whom I have been thrown.

Of the fifteen samples analyzed, three, Nos. 7, 8, and 9, were especially examined with the object of isolating the bacillus of typhoid fever. Measured portions of these samples were seeded on Elsner's gelatine, a medium vaunted to eliminate all bacterial growths save that of the Bacillus *typhi abdominalis* and Bacillus *coli communis*. Although a large number of organisms were studied carefully, none reacted to the Widal-Pfeiffer blood test as does the Bacillus *typhi*, although in other characteristics they were closely allied to these organisms. Also portions of other samples were grown on Parietti bouillon, a very acid carbolized medium, and these growths were examined culturally and under the microscope, but the Bacillus *typhi abdominalis* was not found. One element of trouble has been caused by having the gelatine melt during the warm weather.

In making analyses of the other twelve samples, I have followed the well-known method of Theobald Smith, modified by the method of Hazen and White, i. e., a measured portion is planted on sugar bouillon and submitted to an incubator temperature of 41°C. to 42°C. for from 24 to 48 hours. It is known that at this temperature, many of the common water bacteria are destroyed, and that the intestinal forms survive. These intestinal (suspicious) organisms, in growing, disintegrate the sugar in the bouillon, and the liquid is said to ferment. The gas from this fermentation collects in the appropriate portion of the testing tube, and is itself studied. Usually, the fermentation of the sugar bouillon gives rise

to carbon dioxide (CO_2) and hydrogen gas (H), so the gas formulæ show only the relative amounts of CO_2 and H. Theobald Smith says that if water analyzed in this way ferments the bouillon, and especially if there is free evolution of gas, we may suspect that the water is contaminated by sewage. In fact he declares that, when the species which develop in fermentation solutions, seeded with such water, are transplanted to different media and studied, it is unusual to find bacteria other than the Bacillus *coli communis*, Bacillus *enteritidis*, Bacillus *lactis ærogencs*, and possibly Bacillus *typhi abdominalis*. I do not believe that the last named organism will be isolated in this way, save in a rare instance when it alone is present in the sample seeded. In all, ninety-three different organisms have been isolated and studied, both culturally and microscopically. Of these, fifty-three correspond to the organisms of the colon groups, one being Bacillus *enteritidis* and four Bacillus *lactis ærogencs*. Several were like typhoid, one especially, but did not react with typhoid blood. Thirty-eight were of the proteus groups, the ordinary organisms of putrefaction. The remainder were of little interest.

The significance of these two groups is evident. A water contaminated with those of the colon groups must be considered unfit to drink; for the probable presence of the typhoid germ, if there arise an epidemic of typhoid fever on the water-shed, is evident. The presence of the proteus organism in such quantity indicates much waste albuminoid material supplying their food; at the same time disease may arise from their presence in the body.

In conclusion, I find every sample of water contaminated and giving rise to fermentation. From all but three samples fermentation germs were isolated. In these three it is hard to explain why the ferment was not found. However, it is well-known that many organisms growing together give rise to peculiar conditions not found in any single growth, a peculiarity of symbiosis not readily explained.

Appended,* there is a tabulation of the work and results secured in the analysis of each of the fifteen samples of water examined. The source of each sample is shown, also the time of its collection; together with the result of seeding it upon Wurtz litmus agar and upon lactose and glucose bouillon, all of which were maintained at incubator temperature of 40°C. to 41°C. The Wurtz agar plates gave evidence of the growth of organisms at this high temperature, with or without the formation of an acid. The sugar bouillon, in fermentation tubes, gave evidence of their power to disintegrate, or ferment sugars. The results of these tests are characteristic of those organisms usually found in waters, contaminated with human or animal excretions, and they are used to determine the fitness of waters for domestic use. The table also shows briefly the more marked

*See Table on Page 330.

cultural and physiological characteristics of the organisms which were selected from each fermentation tube. These special organisms, the study of which has only been sufficient to appropriately group them, were chosen as representing most clearly those, whose presence indicate fæcal contamination.

Most respectfully,

EUGENE WASDIN, M. D.

June 12, 1897.

RESULTS OF BACTERIOLOGICAL EXAMINATION OF FIFTEEN DIFFERENT SAMPLES OF WATER, COLLECTED FROM THE PUBLIC WATER SUPPLY OF PITTSBURGH.

Number	Source of Sample	Calendar Date of Collection. 1897	Reactions with Original Sample of Water: Gas Production: Lactose	Gas Production: Glucose	Wurtz Litmus Agar: Blue	Wurtz Litmus Agar: Red	Reactions Produced by Bacteria, Isolated from Original Sample: No. of Cultures Inc. in Tab'l'n	Nutrient Gelatine: Liquefaction	Nutrient Gelatine: Gas	Motility	Fermentation Tubes: Glucose Bouillon: Gas	Glucose Bouillon: Reaction	Lactose Bouillon: Gas	Lactose Bouillon: Reaction	Coagulation	Litmus Milk: Color	Litmus Milk: Days Grown	Character of Growth on Potato	Indol	Remarks
1	Highland Reservoir	March 19	+	+	+	+	1	+	o	+	o	Alkaline	o	Alkaline	+	——	4	Dry-Brown-Wrinkled	o	Suspicious, Fermenting Germ not Found
2	Herron Hill Reservoir	March 19	+	+	+	+	1	+	o	+	o	Acid	o	Acid	+	Pink	4	Moist-Yellow-Expansion	o	Suspicious
3	Tap at Schenley Park	March 19	+	+	+	+	1	+	o	+	o	Acid	o	Acid	+	Pink	4	Moist-Creamy-Expansion	o	Suspicious
4	Highland Reservoir	March 24	+	+	+	+	2	o	+	+	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	+	——	4+14	Moist-Creamy-Expansion	o	Intestinal, Colon Group
							1	+	o	+	o	Alkaline	o	Alkaline	o	——	—	Dry-Brown-Granular	o	——
5	Herron Hill Reservoir	March 24	+	+	+	+	3	o	+	+	$\frac{H}{CO_2} = \frac{0}{2}$	Acid	$\frac{H}{CO_2} = \frac{2}{1}$	Acid	+	Pink	14	Moist Glistening-Furrowed-Granu'r	o	Suspicious
							1	+	o	+	o	Alkaline	o	Alkaline	o	——	—	Opaque Center-Lighter Edges	+	Suspicious
6	Tap at Schenley Park	March 24	+	+	+	+	1	o	+	+	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	+	——	4	——	+	Colon Group
							1	o	+	+	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	$\frac{H}{CO_2} = \frac{1}{2} + NH_4$	Acid	+	Pink	14	——	o	Colon Group
							1	+	o	o	o	Alkaline	o	Alkaline	o	Heliotrope	—	Moist-Creamy-Expansion	o	Proteus
7	Bedford Basin	April 6	+	+	+	+	1	o	+	+	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	+	Violet	5	Light Brown-Moist-Expan.	+	Colon Group
8	Garfield Tank	April 6	+	+	+	+	1	o	+	+	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	o	Pink	14	Moist-Brown'h-Expansion	o	Colon Group
9	Tap at Colwell and Logan Sts.	April 6	+	+	+	+	1	+	o	+	——	Acid	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	+	Pink	5	Moist-Wrink'd-Expansion	o	Proteus
10	Highland Reservoir	April 14	+	+	o	+	1	o	o	+	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	+	Pink	6	Moist-Brownish-Glistening-Expan.	+	Colon Group
11	Herron Hill Reservoir	April 14	+	+	o	+	1	o	o	+	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	o	Heliotrope	14	——	+	Colon Group
12	Tap at Point	April 14	+	+	o	+	1	o	o	+	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	+	Pink	14	——	o	Colon Group
13	Tap on South Side	April 22	+	+	o	+	1	o	o	+	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	$\frac{H}{CO_2} = \frac{1}{1}$	Acid	+ o	Pink	5	Moist-Creamy-Exp Gas Bubbles	o	Bacillus lactis aerogenes. Colon Group
14	Tap on South Side	April 22	+	+	o	+	1	o	o	+	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	o	Pink	14	Creamy-Exp'n. Gas Bubbles	+	Bacillus lactis aerogenes. Colon Group
15	Tap on South Side	April 22	+	+	o	+	1	o	o	+	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	$\frac{H}{CO_2} = \frac{1}{2}$	Acid	o	Pink	—	Moist-Glist'ng-Expansion	+	Colon Group

NOTES:—The plus sign (+) means that the reaction is present.
The zero sign (o) means that the reaction is not present.
The dash sign (-) means that no determination was made.

REPORT

UPON

Bacteriological and Microscopical Investigations,

BY

WM. R. COPELAND,

BACTERIOLOGIST.

APPENDIX No. 4.

APPENDIX No. 4.

MR. MORRIS KNOWLES,

Resident Engineer,

Pittsburgh Filtration Commission.

SIR :—

I beg to submit the following report on the bacteriological and microscopical investigations made in connection with the experiments conducted by the Filtration Commission. The numbers of bacteria, which were found in the effluents from the various filters and in samples from other sources, have been reported to you from time to time.

The work consisted principally of the determination of the number of bacteria in samples of Allegheny River water, collected before and after filtration. During part of July and the month of August, 1897, samples were collected daily; and from September, 1897, to February, 1898, samples were collected at least twice a day. After February, 1898, samples were collected several times each day. Samples were also collected several times each month from the water supplies of Pittsburgh and vicinity.

Two other branches of work which were pursued as time allowed were devoted to the isolation of species of bacteria, and to the determination of the species and numbers of micro-organisms* in waters collected from the sources described in the preceding paragraph.

The following report, therefore, has been divided into three parts. The first division describes the methods which were used to determine the numbers of bacteria in the waters examined; the second, methods used to isolate species of bacteria; the third, the method used in counting and enumerating the number of micro-organisms found. Table I, in Part II, contains a list of the species of bacteria found, and the tables appended to Part III contain lists of the micro-organisms.

From July 1 to August 23, 1897, the bacteriological work was performed in the laboratory of the Bureau of Health, Department of Public Safety. After August 23, the work was done in a small laboratory near the filter plant at Brilliant. A portion of the time of the laboratory force was devoted to collecting samples from various points on the Allegheny River, to recording gage readings, to making out record sheets of the operations of filters, and to general supervision of the operations of the experimental filter plant.

* The term micro-organisms, as used in this report, includes the minute forms of aquatic life, excepting bacteria, which must be studied by means of the microscope.

PART I.

METHODS EMPLOYED TO DETERMINE THE NUMBERS OF BACTERIA IN WATER.

The numbers of bacteria contained in waters were determined by "Koch's Plate Culture" method. The glassware employed in these determinations was boiled in a strong solution of bichromate of potash and sulphuric acid. All traces of the latter were removed, before the articles were used, by washing them in filtered water until the rinse water gave a neutral reaction with methyl orange. Glassware was sterilized by heating it for two hours in a dry sterilizer at 200°C.

The media used in making plate cultures were nutrient gelatine, nutrient glycerine agar, and nutrient litmus lactose agar. The gelatine manufactured by Comte Fils of Magdebourg, and labeled *premiere qualite*, was employed because it had been adopted in other laboratories where special attention is given to the bacteriology of water. Thread agar, free from acid, and double distilled glycerine were used to make nutrient agar. Lactose agar was prepared by adding two per cent. of powdered crystalline lactose to nutrient glycerine agar neutral to phenolphthalein; four drops of sterile aqueous solution of blue litmus were added to the lactose agar just before plating. The meat infusion used in media was prepared by soaking one part of finely chopped lean beef in two parts of distilled water for twenty hours at a temperature of 10°C. Litmus has been employed extensively, in other laboratories, as an indicator in titrating nutrient gelatine. Mr. Geo. W. Fuller,[1] however, has pointed out that phenolphthalein is more sensitive than litmus to weak organic acids. Phenolphthalein was used, therefore, in titrating nutrient media. Sodium hydrate was used to neutralize media. When hydrochloric acid is added to nutrient media containing an excess of sodium hydrate, salt is formed. It is pointed out in another article,[2] in the Journal to which reference has just been made, that salt is unfavorable for the development of bacteria in media. In order to avoid the formation of salt, sulphuric acid was used instead of hydrochloric to acidify nutrient media. Twentieth normal solutions of sodium hydrate and sulphuric acid were used in making titrations. Five cubic centimeters of media, diluted with 50 cubic centimeters of distilled water, were boiled for two minutes in a white porcelain dish and the titrations made while the mixture was hot.

The question of reaction of nutrient media is taken up more at length on page 339 of this report. Nutrient gelatine and agar were

[1] "Proper Reaction of Nutrient Media for Bacterial Cultivation." Geo. W. Fuller, Journal of the American Public Health Association, Vol. XX, Oct., 1895, p. 565, et seq.

[2] "The Influence of Variations in the Composition of Nutrient Gelatine upon the Development of Water Bacteria."

Prof. Wm. T. Sedgwick and S. C. Prescott, Journal American Public Health Association, Vol. XX, 1895, p. 450 et seq.

sterilized for five minutes in an autoclave at a pressure of 15 pounds. Lactose agar was sterilized for 25 to 30 minutes in an Arnold steam sterilizer on each of three consecutive days. All kinds of media were re-sterilized for ten minutes in boiling water, or in an autoclave for one minute at 15 pounds pressure before plating. For further particulars in regard to the method of preparing nutrient media, the reader is referred to the Twenty-Seventh Annual Report of the Massachusetts State Board of Health.*

PLATING.

This process used in making cultures of samples of water in petri dishes is known as plating. The dishes used in plating varied somewhat in size. An average dish measured, inside, three and one-half inches in diameter and one-half an inch in depth. The numbers of bacteria in the waters analyzed ranged from many thousands in samples collected from the Allegheny River, to a few cells in the filtered water. Therefore, in order to give each colony ample food material for development, waters which contained more than three or four hundred bacteria per cubic centimeter were generally diluted with known volumes of sterile water before plating. This practice was followed in examining waters which contained large numbers of bacteria, except in a few cases when dealing with samples from new sources or collected for the purpose of illustrating some special point. Waters which contained from 5,000 to 10,000 or more bacteria per cubic centimeter were diluted one part in fifty; samples, containing from 2,000 to 5,000 per cubic centimeter, were diluted one part in twenty-five of sterile water.*

After plating the samples of water, the petri dishes were set in an ice chest, to allow the nutrient media to harden; and several hours later they were transferred to a thermostat. The plates were examined daily; and as soon as colonies had developed on a given plate to such a size that they threatened to destroy their neighbors, the number of colonies was counted, using a hand lens. Plates containing many liquefied colonies were placed in the ice chest after counting. The plates could generally be kept there for a day or two longer, because the low temperature checked the rapid development of liquefying forms. During these extra days, slow growing species had time to develop. The whole number of colonies finally counted contained, therefore, a greater proportion of the actual number of colonies on the plate than would have been obtained by keeping the plates at the warmer temperature of the thermostat, where the liquefying forms would have developed until they had turned the whole mass of nutrient media into water.

*Twenty-Seventh Annual Report of the Massachusetts State Board of Health, 1895, p. 592, et seq.

TEMPERATURE.

One of the most perplexing problems encountered in the whole process of plate culture came from changes in temperature at different seasons of the year. The mercury often rose to 36°C. in the laboratory in summer and, in winter, it sometimes dropped to 15°C. on cold nights. The average daily temperatures in the thermostat, are given by months, in the following table:—

TABLE A.

*Average Temperatures in Thermostat, by Months, in Degrees Centigrade.**

Month.	Year.	Average Daily.	AVERAGE DAILY		Difference Between Average Maximum and Minimum.	EXTREMES DURING THE MONTH.	
			Maximum.	Minimum.		Maximum.	Minimum.
July	1897	23.4	23.6	23.3	0.3	25.0	22.0
August	"	24.7	25.0	24.5	0.5	27.0	24.0
September	"	24.9	25.0	24.7	0.3	27.0	22.0
October	"	21.5	21.6	21.3	0.3	24.0	20.0
November	"	18.5	19.4	17.2	2.2	22.0	16.0
December	"	19.0	20.6	17.3	3.3	23.0	15.0
January	1898	18.6	19.9	16.4	3.5	23.0	14.0
February	"	19.5	21.0	16.9	4.1	22.0	9.0
March	"	20.6	22.8	18.9	3.9	28.0	15.0
April	"	17.3	18.4	16.3	2.1	20.0	13.0
May	"	19.6	20.2	18.9	1.3	23.0	15.0
June	"	19.1	19.4	18.9	0.5	26.0	18.0
July	"	18.5	18.6	18.3	0.3	20.0	18.0
August	"	18.2	18.3	18.1	0.2	19.0	17.5
September	"	17.7	18.0	17.5	0.5	18.5	16.0
October	"	19.5	20.5	18.2	1.3	26.0	15.0
November	"	18.1	19.4	17.5	1.9	21.0	15.0

The figures given in the preceding table show that the average temperature varied considerably from day to day; the variations between the maximum and minimum often amounting to several degrees. The table also indicates that, in general, the temperatures were several degrees higher during the summer and autumn of 1897, than during the corresponding months of 1898. These conditions were due to the following causes:—

The temperatures were high in the summer of 1897 because they were governed wholly by the temperature of the laboratory which was about the same as that of the outside air.

After October a pipe leading from the water main was connected with the thermostat, for the purpose of keeping a constant current of cold water in circulation between the walls. Beside this device, a glass tube, holding a column of mercury, was hung in the water between the walls.

*For a list of daily temperatures, see Table F at the end of Part 1, Page 342.

By expanding and contracting, the mercury decreased or increased the stream of gas which supplied a lighted Bunsen burner placed beneath the bottom. Theoretically, therefore, the temperature of the current of water circulating through the walls should have kept the column of mercury expanded to such a point that the flame of gas would supply just enough heat to maintain the temperature of the inner chamber of the thermostat at a given degree. Unfortunately, however, the river water often carried quantities of mud in suspension. This mud settled in the valves and stopped the current of water from circulating. Meantime, the gas flame beneath the thermostat continued to heat the water between the walls. This flame soon raised the temperature within the thermostat several degrees. Under such a condition the column of mercury expanded to a point where it cut off the supply of gas almost entirely. The flame then dropped to such a small jet that a slight current of air would blow it out. On the other hand, changes in the water pressure often increased the current of water in circulation. At such times a cold stream poured into the thermostat. If the gas flame had blown out and if no watchman was near to relight it, the temperature of the thermostat dropped several degrees. These conditions were modified in the spring of 1898, by having one of the assistant filter attendants read the temperatures frequently at night and adjust the flowing water. The preceding table shows the advantage of this supervision, as the difference between the maximum and minimum temperatures decreased noticeably in April and in May. During the summer weather the river water in the main became warm and the temperature often rose to 25°C. This was so high that the water could not be used to regulate the temperature of the thermostat. The effect of warm weather was lessened in the summer of 1898, by placing gelatine plates in a barrel sunk deep in a bank of earth and protected by doors from the heat of the sun. The preceding table shows that this simple device maintained a fairly uniform temperature during the summer of 1898.

Nutrient gelatine melted during July and August, 1897, when allowed to stand for a few hours at the high temperature of the laboratory. Comparisons made by plating duplicate samples of water on gelatine and agar, in warm weather, showed that when gelatine plates liquefied the numbers of colonies ran higher on nutrient glycerine agar than on gelatine. As these results corroborated the experience encountered at Lawrence and in other laboratories where glycerine agar has been used extensively, all samples were plated on glycerine agar during August and September, 1897. Nutrient gelatine, however, is used more extensively than agar in making examinations of water. As soon, therefore, as cooler weather returned in the fall, the samples were plated on gelatine instead of agar, and this practice was continued until the end of the work.

Number of Days During Which Plates Were Allowed to Develop.

Variations in temperature made it desirable to allow plates to develop for different periods at different seasons of the year. The high temperature in the summer of 1897 was favorable for a rapid development of bacteria; during this period, the plates were kept from two to three days. When cooler weather began in the fall and the temperature of the thermostat dropped from 23° or 24° to 21°C. the colonies of bacteria developed more slowly. Under this condition, the plates were kept from three to four days. As a result of allowing plates to develop for one day longer the number of colonies increased as shown in the following table:—

TABLE B.

Number of Colonies Which Developed on Gelatine Plates, Growing for Three and Four Days, at 21° Centigrade.

Date. 24 Hours Ending 9.00 A. M. 1897.	Source of Sample.	Bacteria Per Cubic Centimeter. 3 Days.	4 Days.
Sept. 29	Allegheny River at Millvale	3,925	4,325
" 29	Effluent from Crib at Millvale	2,850	3,125
Oct. 2 & 3	Gate Chamber, (Average of Two Days)	4,675	6,025
" " "	Effluent, Filter No. 1, (Average of Two Days)	19	23
" " "	Effluent, Filter No. 2, (Average of Two Days)	140	148
" 5	Tap in Wilkinsburg	132	148
" 6	Allegheny River at Hulton	11,750	12,250
" 6	Effluent from Crib at Hulton	4,960	6,336
" 8	Gate Chamber	18,200	18,900
" 8	Settled Water	4,025	6,100
" 8	Effluent, Filter No. 2	12	18
" 9	Effluent, Filter No. 1	19	23

This table shows that the number of colonies increased gradually from the third to the fourth day. After October 5, 1897, therefore, all plates were kept for four days, but when plates were kept for more than four days at this temperature, the bacteria liquefied the nutrient gelatine.

On November 11, and December 18, 1897, the temperature of the thermostat rose to 25°C. for reasons described on page 337, and in consequence the nutrient gelatine in the plates melted. In order to prevent a recurrence of such a disastrous increase, the temperature of the thermostat was reduced to 18°C. on December 24, 1897. The reason for making the change was, that, even when the temperature rose three or four degrees, it only ran up to 22°C. instead of to 24°C.; nutrient gelatine, which melted at the latter temperature, remained solid at 22°C.

When the plates were kept at 18°C. the colonies developed slowly. Under such conditions the number of colonies increased for five or six days. This point is illustrated in the following table, which gives, for each sample, the numbers of colonies counted upon the plates for successive days:—

TABLE C.

Number of Colonies Which Developed on Gelatine Plates, Growing for Five and Six Days at 18° Centigrade.

Date, 24 Hours Ending 9.00 A. M. 1897.	Source of Sample.	Bacteria Per Cubic Centimeter. 5 Days.	6 Days.
Dec. 24	Settling Basin	8,350	11,300
" "	Tap at Herron Hill	7,000	7,150
" "	Effluent, Tile B	1,000	1,650
" "	Effluent, Tile D	2,800	3,500
" 25	Gate Chamber	4,550	5,250
" "	Gate Chamber	4,200	4,800
" "	Settling Basin	7,450	8,600
" "	Effluent, Filter No. 1	186	211
" "	Effluent, Filter No. 2	155	157
" 27	Gate Chamber	2,800	3,250
" "	Effluent, Filter No. 1	59	94
" "	Effluent, Filter No. 1	48	57
" 28	Gate Chamber	2,350	2,800
" "	Settling Basin	4,950	5,350
" "	Effluent, Filter No. 1	69	75
" "	Effluent, Filter No. 2	197	222
" "	Effluent, Tile C	675	1,075
" "	Effluent, Tile F	650	850
" 29	Gate Chamber	1,750	2,000
" "	Settling Basin	5,000	5,400
" "	Tap in Allegheny	7,350	8,050
" "	Allegheny River at Etna	26,150	27,400
" "	Tap at Millvale	2,500	3,125

The table shows, as a whole, that, after the plates had been kept for four days in the thermostat and then transferred to the ice chest, the number of colonies counted increased from the fifth to the sixth day. A few plates were kept more than six days, but the liquefying colonies usually developed to such a degree that the number of colonies which could be counted decreased when the plates were kept for a longer period.

REACTION OF MEDIA.

The reaction of a nutrient medium exercises an important influence over the colonies which develop in the medium in which samples of water are plated. If the medium is either too acid or too alkaline, certain species of bacteria will not multiply rapidly, and the number of colonies which are found at the end of a few days will, therefore, be too low. For many years media which were neutral to litmus were used to determine the number of bacteria in water. The neutral point of litmus has a degree of reaction which is described by Mr. George W. Fuller* as about

* 27th Annual Report, Massachusetts State Board of Health, 1895, p. 591.

1.3 per cent. acid, on a scale established in titrating organic compounds with phenolphthalein as an indicator. This writer recommended that media should be made more acid than this, or about 1.5 per cent. acid to phenol. The article cited states, in another paragraph, "The evidence at hand shows that the degree of reaction which is most favorable for bacterial growth varies somewhat with different species of bacteria, and perhaps with seasons of the year."

As suggested by this opinion, samples of water from different sources were plated from time to time in media having different degrees of reaction. The results obtained are given in the following table:—

TABLE D.

Number of Colonies of Bacteria Which Developed in Nutrient Media Having Different Degrees of Reaction.

Date, 24 Hours Ending 9.00 A. M.	Year,	Degrees of Reaction in Per Cent. 2.0	1.5	1.0	0.5	Neutral.
		River Water.				
July 28,	1897.....	3,900	6,300	4,200	5,600	.....
Oct. 7,	"	.....	18,550	8,250	7,550	7,400
Oct. 9,	"	.....	22,200	18,550	19,250	18,500
Oct. 11,	"	.....	32,730	22,000	17,130	18,200
Nov. 22,	"	4,600	9,750	11,700	14,600	.....
Dec. 4,	"	10,700	8,700	13,700	8,700	.....
March 9,	1898.....	2,180	7,300	5,200	4,300	3,000
March 17,	"	23,500	16,000	13,450	8,000	10,300
March 17,	"	16,100	15,400	13,200	14,100	16,700
March 25,	"	20,500	21,050	22,000	18,000	16,200
May 3,	"	3,000	3,400	3,300	2,900	.....
May 22,	"	5,400	6,650	7,500	6,500	.....
May 26,	"	13,800	18,500	13,600	13,750	.....
		Effluents from Sand Filters.				
July 31,	1897.....	37	61	34	69	...
Oct. 7,	"	...	14	22	21	16
Oct. 9,	"	...	27	31	23	23
Oct. 11,	"	...	186	219	111	70
Nov. 22,	"	153	350	384	524	...
Nov. 22,	"	174	498	580	500	...
Dec. 4,	"	66	118	172	112	...
May 3,	"	315	392	370	300	...
May 21,	"	68	80	82	73	60
		Miscellaneous Samples.				
July 29,	1897.....	33	72	59	48	...
Sept. 21,	"	30	47	160	79	...
Nov. 16,	"	190	199	412	144	...
March 9,	1898.....	322	161	130	18	...
March 9,	"	119	139	110	122	79
March 17,	"	110	104	173	142	71
May 1,	"	60	42	28	15	...
May 4,	"	715	810	790	710	...
May 26,	"	58	70	48	36	20

This table shows that the most favorable degree of reaction varied somewhat at different seasons of the year.

Guided by the results obtained with the samples of filtered water the reaction of nutrient media was changed in October, 1897, from 1.5 to 1.0 per cent.; in November, 1897, from 1.0 to 0.7 per cent.; in December, 1897. from 0.7 to 1.0 per cent.; and in March, 1898, from 1.0 to 1.3 per cent.

TABLE E.

Averages of the Numbers of Bacteria Which Developed in Nutrient Media of Different Degrees of Reaction.

Source of Sample.	Degrees of Reaction in Per Cent.				
	2.0	1.5	1.0	0.5	Neutral.
Raw Water	10,568	14,348	12,050	10,644	12,900
Effluents from Filters..	139	186	205	186	60
Other Effluents	182	183	212	146	57

This table gives the averages of all the comparisons made during the year. It shows that the most favorable reaction lay between 1.5 and 1.0 per cent. The figures obtained up to March 1, 1898, seemed to point to this fact, and after March 1, 1898, all media used for the regular analyses were made with a reaction of 1.3 per cent. A further reason for selecting that special degree lay in the fact that, during the process of sterilizing, the acidity of the media often increased 0.1 or 0.2 per cent. Thus the, reaction of the media, at time of plating, approached, but did not exceed 1.5 per cent.

TABLE F.

RECORD OF DAILY TEMPERATURES IN THERMOSTAT, IN DEGREES, CENTIGRADE.

Date, 24 Hours Ending 9.00 A. M.	July, 1897.			August, 1897.			September, 1897.			October, 1897.			November, 1897.			December, 1897.			January, 1898.			February, 1898.			March, 1898.		
	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	21.0	21.0	21.0	.....	.....	.....	22.0	16.0	19.5	21.0	16.0	18.3	21.0	16.0	19.5	20.0	18.0	19.0
2	.....	.....	.....	25.0	25.0	25.0	25.0	25.0	25.0	21.0	21.0	21.0	.....	.....	.....	22.0	19.0	20.2	21.0	16.0	20.0	21.0	9.0	17.0	20.0	19.0	19.7
3	.....	.....	.....	26.0	25.0	25.5	25.0	24.0	24.5	21.0	21.0	21.0	.....	.....	.....	20.0	19.0	19.7	20.0	15.0	17.7	22.0	9.0	20.5	22.0	16.0	18.7
4	.....	.....	.....	27.0	26.0	26.5	24.0	24.0	24.0	21.0	21.0	21.0	.....	.....	.....	21.0	20.0	20.2	21.0	15.0	19.9	.....	.....	.....	22.0	18.0	19.8
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	21.0	20.0	20.5	.....	.....	.....	21.0	18.0	20.2	22.0	18.0	20.6	.....	.....	.....	23.0	20.0	21.3
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	21.0	18.0	18.7	19.0	16.0	18.0	.....	.....	.....	23.0	21.0	22.0
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	22.0	17.0	20.5	18.0	16.0	17.3	.....	.....	.....	23.0	16.0	19.5
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.0	16.0	17.7	23.0	14.0	17.7	.....	.....	.....	24.0	16.0	20.5
9	.....	.....	.....	.....	.....	.....	25.0	25.0	25.0	20.0	20.0	20.0	.....	.....	.....	20.0	16.0	18.7	18.0	15.0	16.7	.....	.....	.....	24.0	20.0	21.8
10	.....	.....	.....	.....	.....	.....	26.0	25.0	25.5	20.0	20.0	20.0	.....	.....	.....	21.0	20.0	20.2	19.0	15.0	18.0	.....	.....	.....	23.0	19.0	20.5
11	.....	.....	.....	25.0	25.0	25.0	27.0	26.0	26.5	22.0	20.0	21.0	.....	.....	.....	22.0	21.0	21.7	19.0	19.0	19.0	.....	.....	.....	23.0	19.0	20.2
12	.....	.....	.....	25.0	24.0	24.5	27.0	27.0	27.0	22.0	22.0	22.0	.....	.....	.....	22.0	16.0	18.0	19.0	19.0	19.0	.....	.....	.....	23.0	15.0	18.7
13	.....	.....	.....	24.0	24.0	24.0	27.0	27.0	27.0	.....	.....	.....	.....	.....	.....	18.0	18.0	18.0	21.0	19.0	20.0	.....	.....	.....	23.0	20.0	21.5
14	23.0	23.0	23.0	25.0	24.0	24.5	27.0	27.0	27.0	.....	.....	.....	.....	.....	.....	19.0	18.0	18.5	21.0	19.0	20.0	.....	.....	.....	23.0	22.0	22.5
15	23.0	23.0	23.0	.....	.....	.....	.....	.....	.....	24.0	24.0	24.0	.....	.....	.....	21.0	18.0	19.5	19.0	19.0	19.0	.....	.....	.....	23.0	18.0	20.8
16	25.0	23.0	24.0	25.0	25.0	25.0	.....	.....	.....	24.0	24.0	24.0	.....	.....	.....	23.0	18.0	20.0	19.0	15.0	18.0	22.0	16.0	19.5	24.0	22.0	22.7
17	.....	.....	.....	.....	.....	.....	24.0	24.0	24.0	.....	.....	.....	.....	.....	.....	23.0	16.0	20.7	20.0	15.0	17.5	22.0	16.0	20.0	24.0	19.0	21.2
18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	22.0	16.0	19.0	20.0	16.0	18.0	20.0	15.0	18.5	20.0	19.0	19.7	22.0	19.0	20.2
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.0	16.0	17.5	22.0	16.0	20.0	20.0	16.0	19.2	19.0	19.0	19.0	22.0	19.0	19.7
20	24.0	24.0	24.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.0	16.0	18.2	22.0	21.0	21.2	21.0	17.0	19.5	20.0	19.0	19.5	20.0	19.0	19.5
21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.0	19.0	19.7	21.0	18.0	20.2	17.0	17.0	17.0	21.0	19.0	20.0	22.0	20.0	20.3
22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.0	17.0	18.5	21.0	18.0	19.2	20.0	17.0	20.0	21.0	20.0	20.2	28.0	22.0	23.5
23	22.0	22 0	22.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	17.0	16.0	16.5	21.0	16.0	18.2	22.0	16.0	20.2	21.0	18.0	19.2	.....	.....	.....
24	.....	.....	.....	.....	.....	.....	.....	.....	.....	22.0	22.0	22.0	16.0	16.0	16.0	18.0	16.0	17.0	21.0	16.0	18.8	21.0	18.0	19.5	.....	.....	.....
25	24.0	24.0	24.0	24.0	24.0	24.0	.....	.....	.....	22.0	22.0	22.0	17.0	16.0	16.5	19.0	15.0	17.8	21.0	18.0	20.5	22.0	20.0	21.2	.....	.....	.....
26	24.0	24.0	24.0	24.0	24.0	24.0	23.0	23.0	23.0	22.0	21.0	21.5	19.0	17.0	18.2	19.0	15.0	17.5	20.0	16.0	18.5	22.0	20.0	21.2	.....	.....	.....
27	24.0	23.0	23.5	25.0	24.0	24.5	23.0	23.0	23.0	21.0	21.0	21.0	22.0	18.0	20.2	19.0	16.0	17.5	.....	.....	.....	21.0	15.0	17.7	.....	.....	.....
28	.....	.....	.....	25.0	24.0	24.5	23.0	22.0	22.5	.....	.....	.....	21.0	19.0	20.5	16.0	16.0	16.0	18.0	16.0	17.0	20.0	18.0	18.5	.....	.....	.....
29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	21.0	21.0	21.0	22.0	16.0	19.0	21.0	16.0	18.7	.....	.....	.....	.....	.....	.....
30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	19.0	16.0	18.7	22.0	16.0	19.0	18.0	16.0	17.0	.....	.....	.....	.....	.....	.....
31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	20.0	16.0	18.3	18.0	16.0	17.0	.....	.....	.....	.....	.....	.....
Av'gs,	23.6	23.2	23.4	25.0	24.5	24.7	25.1	24.8	24.9	21.6	21.3	21.5	19.4	17.2	18.5	20.6	17.3	19.1	19.9	16.4	18.6	21.0	16.9	19.5	22.8	18.9	20.6

TABLE F,—(Continued.)

RECORD OF DAILY TEMPERATURES IN THERMOSTAT, IN DEGREES, CENTIGRADE.

Date. 24 Hours Ending 9.00 A. M.	April, 1898.			May, 1898.			June, 1898.			July, 1898.			August, 1898.			September, 1898.			October, 1898.			November, 1898.			December, 1898.		
	Max.	Min.	Aver.	Max.	Min.	Aver	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.	Max.	Min.	Aver.
1	.....	.....	.....	18.0	17.0	17.2	22.5	21.5	22.0	19.5	19.0	19.2	.....	.....	.....	18.0	18.0	18.0	.....	.....	.....	20.0	18.0	18.5	19.0	17.0	18.0
2	.....	.....	.....	19.0	18.0	18.2	25.0	22.0	24.2	19.5	19.0	19.2	.....	.....	.....	18.5	18.0	18.2	22.0	22.0	22.0	20.0	17.0	18.7	19.0	18.0	18.3
3	.....	.....	.....	20.0	18.5	18.8	25.7	24.0	25.1	20.0	19.0	19.5	18.5	18.5	18.5	.....	.....	.....	24.0	22.0	23.0	18.0	17.0	17.8	19.0	17.0	17.8
4	18.0	13.0	15.7	20.0	18.5	19.2	26.0	25.0	25.9	21.0	20.0	20.5	19.0	18.5	18.7	.....	.....	.....	26.0	24.0	25.3	18.0	18.0	18.0	20.0	18.5	19.1
5	18.0	14.0	16.5	20.0	18.0	18.9	26.0	22.0	22.9	21.0	20.0	20.5	19.0	18.0	18.5	18.0	18.0	18.0	25.0	24.0	24.5	18.0	18.0	18.0	20.0	17.5	18.5
6	22.0	18.0	17.0	19.0	16.0	18.1	18.0	18.0	18.0	20.0	19.0	19.5	18.5	18.0	18.2	18.0	18.0	18.0	26.0	20.0	24.3	19.0	18.0	18.5	20.0	18.0	18.6
7	19.0	18.0	18.2	18.0	16.0	17.7	18.0	18.0	18.0	19.0	19.0	19.0	18.5	18.0	18.2	18.0	18.0	18.0	22.0	19.0	21.2	18.0	18.0	18.0	20.5	18.5	19.7
8	19.0	16.0	17.2	18.0	15.0	15.7	18.5	18.5	18.5	19.0	18.5	18.7	18.0	18.0	18.0	18.0	18.0	18.0	21.0	19.0	20.0	18.0	17.5	17.8	19.5	18.0	18.2
9	20.0	17.0	18.0	16.5	16.0	16.4	18.0	18.0	18.0	18.5	18.0	18.2	18.0	18.0	18.0	18.0	18.0	18.0	21.0	19.0	20.5	19.5	17.5	19.0	19.0	18.0	18.7
10	20.0	13.0	16.0	16.5	16.0	16.2	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.5	17.7	18.0	18.0	18.0	19.0	19.0	19 0	21.0	18.0	19.1	18.0	18.0	18.0
11	19.0	18.0	18.5	18.0	16.0	17.7	18.0	18.0	18.0	18.0	18.0	18.0	17.5	17.5	17.5	.....	.....	.....	20.0	19.0	19.5	21.0	17.5	18.8	18.0	18.0	18.0
12	19.0	17.0	18.0	19.0	18.0	18.9	18.0	18.0	18 0	18.0	18.0	18.0	17.5	17.5	17.5	.....	.....	.....	19.0	19.0	19.0	20.0	17.5	18.6	18.0	18.0	18.0
13	19.0	17.0	17.7	19.0	18.0	18.9	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.5	17.7	.....	.....	.....	20.0	18.5	19.3	19.0	18.0	18.7	19.0	17.0	18.2
14	18.0	17.0	17.2	19.0	18.0	18.6	19.5	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	.....	.....	.....	18.5	18.5	18.5	19.5	19.0	19.1	20.0	19.0	19.5
15	18.0	17.0	17.2	20.0	19.0	19.1	19.0	18.0	18.3	18.0	18.0	18.0	18.0	18.0	18.0	18.5	18.5	18.5	19.0	17.0	18.3	19.5	18.5	18.8	19.0	17.0	18.5
16	19.0	17.0	17.5	20.5	20.0	20.1	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.5	17.0	17.7	18.0	16.0	17.2	19.0	18.0	18.5	19 0	17.0	18.0
17	17.0	16.0	16.5	20.0	18.5	19.5	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.0	17.5	16.0	15.0	15.2	19.5	18.0	19.0	19.0	18.0	18.5
18	20.0	17.0	18.1	20 0	18.5	19.5	18.0	18.0	18.0	18.5	18.0	18.2	18.5	18.0	18.2	18 0	18.0	18.0	18.0	15.0	16.8	21.0	16.5	18.7	19.0	19.0	19.0
19	19.0	18.0	18.2	20.0	19.0	19.6	18.0	18.0	18.0	18.5	18.0	18.2	19.0	18.5	18.7	18.0	17.5	17.7	18.5	17.0	17.9	19.0	16.5	18.0	19.0	17.0	18.7
20	19.0	17.0	18.0	22.0	20.0	20.2	18.0	18.0	18.0	18.5	18.0	18.2	19.0	19.0	19.0	17.5	16.0	16.7	17.5	16.0	16.8	20.0	15.0	17.4	19.0	17.0	18.0
21	17.0	16.0	16.0	22.0	21.5	21.7	18.0	18.0	18.0	19.0	18.5	18.7	19.0	19.0	19.0	17.0	16.0	16.5	18.0	16.0	17.2	20.0	18.0	18.6	18.0	17.0	17.5
22	17.5	16.0	17.0	22.5	21.5	21.9	18.0	18.0	18.0	19.0	18.0	18.5	19.0	19.0	19.0	17.5	17.0	17.2	17.0	17.0	17.0	19.0	18.0	18.6	19.0	17.0	18.2
23	17.0	16.0	16.5	22.5	21.2	21.5	18.0	18.0	18.0	18.0	18.0	18.0	.....	....	.....	18.0	17.5	17.7	17.0	16.0	16.5	19.0	17.0	18.0	.....	.....	.....
24	18.0	16.0	17.0	22.0	21.0	21.7	18.0	18.0	18.0	18.0	18.0	18.0	.....	.....	.....	18.0	17.5	17.7	21.0	16.0	18.5	19.0	18.0	18.3	18.0	15.0	16.5
25	18.0	16.0	17.0	22.5	21.0	21.9	18.5	18.0	18.2	18.0	18.0	18.0	.....	.....	.....	18.5	17.5	18.0	21.0	17.0	19.0	21.0	18.5	19.5	19.0	15.0	17.7
26	18.0	17.0	17.7	22.5	21.0	21.6	18.5	18.5	18.5	18.0	18.0	18.0	.....	....	.....	18.5	18.0	18.2	22.0	17.0	19.5	21.0	17.0	18.5	19.0	19.0	19.0
27	18.0	16.0	17.2	21.5	21.0	21.6	18.5	18.5	18.5	18.0	18.0	18.0	.....	.....	.....	18.5	18.0	18.2	23.0	22.0	22.5	19.0	17.0	18.0	19.0	11.0	17.0
28	17.0	16.0	16.7	21.5	21.5	21.5	18.5	18.5	18.5	18.0	18.0	18.0	.....	.....	.....	18.5	17.0	17.7	23.0	15.0	19.0	19.0	17.0	18.0	18.0	11.0	15.7
29	18.0	17.0	17.8	22.0	21.5	21.8	18.5	18.5	18.5	18.0	18.0	18.0	.	.....	.....	17.0	16.5	16.7	19.0	15.0	17.5	19.0	18.0	18.5	19.0	18.0	18.3
30	18.0	17.0	17.2	22.5	21.0	22.0	19.0	18.5	18.7	18.0	18.0	18.0	.....	.....	.....	.....	.....	.....	22.0	19.0	20.7	19.0	16.0	17.3	19.0	18.0	18.2
31	.....	.....	... .	23.0	21.0	22.0	.....	.....	.....	18.0	18.0	18.0	.....	.....	.....	.....	.....	.....	22.0	18.0	20.0	.....	.....	.....	19.0	18.0	18.7
Av'gs.	18.5	16.4	17.2	20.2	18.9	19.6	19.4	18.9	19.1	18.6	18.3	18.5	18.3	18.1	18.2	18.0	17.5	17.7	20.5	18.2	19.5	19.4	17.5	18.4	19.0	17.1	18.2

PART II.

Species of Bacteria.

The second part of this Report contains a brief account of the "Species of Bacteria" which were found during October and November, 1897, in the Allegheny River water, before and after filtration; and of those species which were found in greatest numbers in the water supply of Pittsburgh during August and September, 1898. In addition to these studies, a short description is given of tests made for the Bacillus *coli communis*.

There are several facts which must be borne in mind in connection with the study of bacteria. In the first place, these small organisms are living plants; they are so minute that they cannot be identified by their form alone; and, therefore, must be studied under artificial cultivation. The characteristics of species may be made stronger, or they may be modified, by changes in the conditions which surround them. And, finally, bacteriologists have not yet united upon a series of tests which they consider to be sufficiently complete to form a standard method for identifying species of bacteria.

In carrying out the work described in the following pages, the methods were selected from the list described as "Necessary Information Tests" in the "Report of American Bacteriologists" to the "Committee on the Pollution of Water Supplies" of the "American Public Health Association."*

In order to secure suitable material for a study of species of bacteria, pure cultures were made from the clearly defined colonies which developed in nutrient gelatine, seeded with samples of water collected from the sources described on page 346. These cultures were transferred afterward to various media and the reactions which they produced were used to identify the forms.

SPECIES OF BACTERIA FOUND IN THE ALLEGHENY RIVER WATER. BEFORE AND AFTER FILTRATION.

The bacterial efficiency of Filters Nos. 1 and 2 was high during October, 1897. The reason for this was that the number of bacteria was large in the river, and was small in the effluent. During the latter part of November, 1897, the bacterial efficiency decreased. Three or four species of bacteria were often found during these two periods. The names of the species and the number of colonies belonging to each, which were found in a cubic centimeter of the raw and filtered water at the time, are given in the following table:—

* This Report was submitted at the meeting of the Association in Philadelphia, Pa., September, 1897.

TABLE G.

Species of Bacteria Found in the Allegheny River Water, before and after Filtration; During October and November, 1897.

Date, 24 Hours Ending 9.00 A. M.	Source of Sample.	NUMBER OF BACTERIA PER CUBIC CENTIMETER, BELONGING TO THE SPECIES. Including All Kinds of Bacteria.	Bacillus *Albus.*	Bacillus *Ochraceus.*	Bacillus *Fluorescens Liquefaciens.*	Bacillus *Punctatus.*
Oct. 23, 1897.	River Water,	157,500	147,400	22,000	75	50
" 23,	Effluent, Filter No. 1.	18	8	1	...	3
" 23,	Effluent, Filter No. 2.	26	13	2	...	10
Nov. 18,	River Water,	19,000	18,200	350	175	125
" 17, *	Effluent, Filter No. 1.	1,230	1,120	7	84	21
" 18, *	Effluent, Filter No. 2.	5,560	5,530	15	280	35

This table shows that the species which were most common in the river were found in the effluent, both in October and in November. The point of special interest, however, is that the species occurred in very much greater numbers in the effluent in November than in October.

APPLICATION OF BACILLUS PRODIGIOSUS.

The number of bacteria continued to be high during December and January following. In order to determine whether these high numbers were due to the presence of bacteria which found their way to the underdrains between the sand and the concrete walls of the filter, pure cultures of the Bacillus *prodigiosus* were mixed with the raw water and applied to the surface of Filter No. 2. The method used in applying these bacteria was as follows. Gallon bottles, containing a sterile solution of one-tenth of a per cent. of peptone and two-tenths of a per cent. of glucose in distilled water, were inoculated with a pure culture of the B. *prodigiosus.* The bottles were place in a thermostat at a temperature of about 18°C., and allowed to incubate for four days. Portions of this mixture were scattered over the surface of the water on the filter every half hour for ten hours, beginning at 9.00 A. M., January 28, and again at 9.00 A. M., January 29, 1898. The number of cells of B. *prodigiosus* was determined in each cubic centimeter of the mixture, and the number of cells of B. *prodigiosus* applied was estimated to be about 3,600 per cubic centimeter of water filtered on January 28, and 9,000 per cubic centimeter on January 29.

* A detailed description of the causes of the high numbers in the effluent, at this time, will be found on Page 120 of the Resident Engineer's Report.

TABLE H.

Number of Water Bacteria and of Bacillus Prodigiosus, Found in the Effluent from Filter No. 2, on January 28 and 29, 1898.

Calendar Date, 1898.	Hour.	Number per Cubic Centimeter. Water Bacteria.	Bacillus *Prodigiosus.*	Remarks.
Jan. 28.	8.20 A. M.	218	0	Before Application.
"	12.00 M.	260	0	
"	2.00 P. M.	294	0	Average Number of
"	3.00 "	230	0	Bacillus *prodigiosus*
"	4.00 "	238	0	Applied, 3,600 Per
"	5.00 "	278	0	Cubic Centimeter.
"	6.00 "	230	0	
"	8.20 "	172	2	
"	10.00 "	166	0	
"	12.00 Mid't.	352	0	
Jan. 29.	2.00 A. M.	328	0	
"	4.00 "	332	0	Average Number of
"	6.00 "	338	0	Bacillus *prodigiosus*
"	8.00 "	313	0	Applied, 9,000 Per
"	8.56 "	176	0	Cubic Centimeter.
"	10.05 "	114	6	
"	12.00 M.	144	1	
"	2.00 P. M.	308	0	
"	3.06 "	167	1	
"	4.04 "	145	5	
"	5.00 "	176	4	
"	6.00 "	140	4	
"	8.50 "	131	5	
"	12.00 Mid't.	101	8	
Jan. 30.	2.00 A. M.	111	16	
"	4.00 "	93	16	
"	6.00 "	102	12	

Seven samples of effluent were collected during each period of ten hours; and the records in the preceding table show that very few cells of B. *prodigiosus* were found in these samples. They occurred more frequently in samples collected after the ten hours had passed than during the period of application. This fact goes to prove that the cells of B. *prodigiosus* did not pass readily from the surface to the underdrains. Data, obtained from experiments made at Lawrence, Mass., indicate that cells of B. *prodigiosus* may pass through a sand filter in small numbers. The presence, therefore, of the few cells which appeared in the effluent from Filter No. 2, after the application was concluded, did not prove that channels had been formed between the bed of sand and concrete walls of the filter.

SPECIES OF BACTERIA FOUND IN SAMPLES OF ALLEGHENY RIVER WATER, COLLECTED FROM THE GATE CHAMBER AND FROM RESERVOIRS AND TAPS IN PITTSBURGH.

Eight sets of samples were collected from the gate chamber, from each of three reservoirs, and from taps in residences near the reservoirs. One set of samples was also collected from a tap in the heart of the

city. When these waters were plated in nutrient gelatine many colonies of bacteria developed which had characteristic forms. Other colonies could not be distinguished so easily. In selecting material from which to take cultures for special study, colonies were chosen which represented the different kinds on each plate. As soon as pure cultures had been obtained of these forms, they were compared, one with another, by making cultures in nutrient gelatine contained in plates and test tubes. By this method many duplicates were detected. For the purpose of final study, cultures were selected, some of which were representative of the duplicate forms, and others of forms having special characteristics.

The organisms used in making the tests were taken from cultures which had been grown for 48 hours on nutrient glycerine agar (reaction 1.5 per cent.). In order to prepare these stock cultures, the organisms in the original samples were transferred to gelatine plates; and from the plates pure cultures were transferred to tubes of gelatine. From these tubes they were transferred to bouillon (reaction 1.5 per cent.), then from the first tube of bouillon to a second, and, finally, from the second to the surface of nutrient glycerine agar. During each of these stages the organisms were allowed to develop for 48 hours at 18°C., before they were transferred to a new medium.

A list of the species which were found in water taken from taps in Pittsburgh, and which gave the most characteristic reactions, are presented, together with the results of the tests, in Table I.* The reactions which are recorded in this table were obtained by allowing the cultures to develop for ten days at from 17° to 19°C.

The thermal death point was found by inoculating each of five tubes, containing 10 c. c. nutrient broth (reaction 1.5 per cent. acid), three times with a platinum wire loop filled with a drop of bouillon containing a pure culture of a given species. One of these tubes was placed in a water bath (depth of water about three inches), having a temperature of 50°C.; other tubes were placed in baths at temperatures of 53°, 56°, and 59°C. The tubes were kept in the baths for ten minutes. They were watched carefully and the temperatures maintained exactly at the specified point. After they had been taken out from the bath, they were placed in ice water until cold, and then set in an incubator at about 18°C. The thermal death point is given, as lying between the point where a growth was found and the point where the tubes were sterile. All cultures were examined at the end of ten days.

The results obtained in the tests are recorded either as positive or negative. Reactions which were well defined are recorded by a plus sign, (+). In cases where no reaction was found or where they were ill defined at the end of ten days they are recorded by a zero, (0).

*Opposite Page 348.

In making the diagnoses of the various organisms, they were not tested for pathogenic properties. The time at the disposal of the Commission was too limited to make such tests complete.

Tests for the Bacillus Coli Communis.

During the months of July and August, 1897, several cases of typhoid fever developed in the 21st Ward of Pittsburgh, and in one of the neigboring towns. Samples were collected from certain taps, springs or wells, and milk used by the families where the fever prevailed. The number of bacteria in the samples was determined; and further tests of the water and milk were made by plating them on Wurtz litmus lactose agar. These agar plates were allowed to develop for 14 hours in a thermostat, at a temperature of 38°C. or 39°C.

Under such conditions the Bacillus *coli communis* should produce bright red colonies. Cultures were taken, therefore, from the colonies on these plates which possessed the characteristic form of colonies of the B. *coli communis* and were transplanted into tubes of milk, nitrate, indol, and fermentation solution, also as stab cultures in tubes of nutrient gelatine.

Cultures which gave reactions in these media characteristic of *coli* were considered to belong to the colon group and to be indicative of fæcal contamination. Similar tests were made upon samples of water collected from the Allegheny and Monongahela Rivers and from reservoirs and taps in different parts of the city. The results of these tests showed that bacteria which belonged to the colon group were present in samples collected from all of these localities, in numbers ranging from one to six per cubic centimeter at different seasons of the year.

Before closing this part of the report attention should be called to the difficulties encountered in carrying out the work of isolating species of bacteria. As bacteria are living organisms, they have periods of growth and decay. In order to secure the reactions which are characteristic of a given species, cultures must be obtained from a single cell. Otherwise the cultures may contain more than a single species. The vitality of the original cell may be effected very decidedly by the composition of the media in which the organism is growing, and by the length of time during which the organism has been under cultivation. By slight differences in composition of the food material, cultures may be made to produce reactions which differ in degree of intensity. It is also true that the different varieties of a given species produce reactions which differ in their degree of intensity. When the cultures produce such variations, the student's only resource is to make tests of duplicate cultures, taking care to keep all conditions parallel. These tests must proceed slowly and be repeated several times. Such comparisons have been carried out in the work described above as far as time would allow.

PART III.

MICRO-ORGANISMS.

The following portion of the report contains the records of the work performed in identifying the species and in counting the numbers of micro-organisms found in samples of water collected from the Allegheny River, from the gate chamber, from the effluents of the filters, and from the reservoirs in Pittsburgh and in Wilkinsburg.

The samples were collected in clean glass bottles having a capacity of one liter. The bottles were plunged a few inches below the surface, filled with water, corked, and carried to the laboratory at once. The samples were examined by the Sedgwick-Rafter method. Filter funnels used in filtering the waters were of the improved type recommended by D. D. Jackson.* When microscopical examinations are being made of surface waters, 250 c. c. are usually taken from each sample for analysis. As this quantity seemed to be small, 500 c. c. were generally filtered instead. Occasionally, however, some of the waters were very muddy. At such times the material gathered by filtering 500 c. c. would have contained a large amount of clay. This sediment would have interfered with the process of counting the micro-organisms. In order to avoid this complication 250 c. c. of muddy water were taken for analysis.

The micro-organisms, found in the waters examined, varied in species and in numbers at different seasons. Filamentous Algae were never found in any considerable number in the samples of water collected, but they gathered occasionally in quantities on the masonry walls of the gate chamber. In the autumn of 1897, masses of Spirogyra, Oscillaria, and Ulothrix collected there in mats. In April, 1898, Spirogyra, Ulothrix, and Stigeoclonium began to develop in thick masses on the walls; by the latter part of May, 1898, these algae had disappeared almost entirely. During the first week in June a species of Conferva developed luxuriantly. Heavy rains which fell on June 9 and 13, made the river water extremely muddy; and by June 16, 1898, the masses of Conferva had disappeared. During July, 1898, thin, but widely spread mats of an alga resembling Lyngbya papyrina developed on the walls of the gate chamber, and appeared in a few patches on the surface of the sand filters. In August, 1898, Spirogyra collected again in streamers in the gate chamber. After a period, during which the river was clearer than usual, little mats of Spirogyra were found on the surface of the sand when the water was drawn off from Filters Nos. 1 and 2 in order to scrape. The other filter plants were under a roof, and algae did not appear at any time, either in the settling basins, or on the wooden walls of the filters, or on the sur-

*"An Improvement in the Sedgwick-Rafter Method for the Microscopical Examination of Drinking Water."

D. D. Jackson, Technology Quarterly, Vol. IX, December, 1896, p. 271, et seq.

faces of the sand. During summer weather masses of mold, however, developed in the coagulant tubs both of the Warren and Jewell Filters.

Among the other forms of microscopical life which were found, Diatoms were common, and, occasionally, species of Protozoa. Cells of Asterionella (variety gracillima) were found on several occasions in samples collected from the gate chamber, Highland Reservoir and Bedford Basin; also, during August and September, 1898, in great numbers in the Wilkinsburg Reservoir. During July, 1898, great numbers of cells of Dinobryon (variety sertularia) appeared in the samples of water collected in the Bedford Basin. The samples from this reservoir had an odor, at that time, which resembled raw oysters.

Effluents from the sand filters and from the Warren and Jewell Filters were examined several times. No organisms were found in the filtered waters, except when the sand filters had just been scraped, and when an unsufficient amount of coagulant was being applied to the mechanical filters.

The remaining paragraphs contain short descriptions of the sources from which the samples were collected.

Gate Chamber.

The samples taken from the "Gate Chamber" were collected over the inlet of the 6-inch main. These samples were considered to be representative of the Allegheny River, because the 6-inch pipe leading to the filter plant branched from the rising mains, which passed directly from the Pumping Station to the Highland Reservoir.

Settling Basin.

The samples collected as representing the settled water were collected below the surface in a small well, through which this water passed just before flowing on to the surface of the sand filters.

Effluents.

The "Effluents" were collected from taps placed in the outlet pipes, as close to the filter basins as possible.

Highland Reservoir.

The samples marked "Highland Reservoir" were collected from two points. Those samples, which are marked "Highland Avenue Main" were drawn from the water just after leaving the reservoir on the way to the main running down North Highland Avenue. The samples, which are marked "Butler Street Main" were taken from a platform directly over the point where this main leaves the Highland Reservoir.

Herron Hill.

The samples marked "Herron Hill" were collected from a platform directly over the point where the water passes out from the reservoir to the piping system. The water used in filling this basin is pumped from a main leading from Highland Reservoir.

Bedford Basin.

The samples marked "Bedford Basin" were collected a few inches under the surface near the place where the water leaves the basin on its way to the service pipes. This reservoir is filled by pumping from the same main as that from which water is pumped to Herron Hill Reservoir.

South Side Reservoir.

The samples marked "South Side Reservoir" were collected from a platform over the outlet main. The water in this reservoir is pumped directly from the Monongahela River.

Wilkinsburg Reservoir.

The samples marked "Wilkinsburg Reservoir" were collected a few inches under the surface of the water near the bank of the basin. The water in the reservoir is pumped from a crib which lies in the bottom of the Allegheny River. Crenothrix and large numbers of Asterionella were found on several occasions in this reservoir. The presence of these organisms indicates that the basin probably receives considerable ground water, at least at some seasons of the year.

Lists of all the organisms found, together with the dates and sources from which the samples were collected, are given in the following tables.

Respectfully submitted,

WM. R. COPELAND,
Bacteriologist.

December 28, 1898.

ALLEGHENY RIVER,

Organisms Per Cubic Centimeter.

Year.	1897.												1898.		
Month.	Aug.	September.						Oct.	November.			Dec.	March.		
Day.	31	1	4	8	14	17	29	8	11	19	29	4	10	19	26
PLANTS.	44	22	74	91	37	165	99	121	147	75	294	192	21	114	74
Diatomaceæ	23	16	54	56	20	53	71	56	131	55	174	134	21	111	72
Amphora	0	0	1	2	0	2	3	0	0	12	4	6	0	0	0
Asterionella	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0
Cocconema	0	0	0	0	0	0	0	0	0	3	0	0	1	0	0
Cyclotella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella	0	0	0	0	0	0	0	0	0	1	0	0	0	0	6
Diatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Epithemia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia	0	0	1	2	0	1	1	4	0	0	0	0	0	0	0
Fragilaria	0	0	0	0	0	0	0	6	0	0	52	0	1	1	0
Gomphonema	0	0	0	2	0	0	0	0	0	0	0	4	0	9	2
Melosira	2	0	4	0	0	0	0	1	0	1	6	4	0	0	0
Navicula	21	10	32	47	7	42	62	42	101	29	40	82	16	80	54
Nitzschia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Stauroneis	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Synedra	0	4	16	1	3	7	5	1	6	8	68	38	3	4	8
Tabellaria	0	2	0	2	0	1	0	0	24	1	0	0	0	7	2
Chlorophyceæ	21	4	20	34	15	49	24	63	4	20	22	2	0	2	2
Arthrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcus	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Closterium	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Cosmarium	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Desmidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrasterias	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmella	0	0	4	9	4	21	3	62	0	18	20	0	0	0	0
Pandorina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	1	0	0	2	0	0	0	0	0	1	0	0	0	0	0
Protococcus	1	2	5	7	4	4	1	0	0	1	0	0	0	0	0
Raphidium	0	0	1	0	0	0	7	0	0	0	0	0	0	0	0
Scenedesmus	12	2	9	14	6	22	11	1	4	0	0	0	0	0	0
Sphærozosma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirogyra	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0
Staurastrum	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0
Stigeoclonium	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0
Volvox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Cyanophyceæ	2	2	0	1	2	1	4	2	12	0	38	16	0	1	0
Chroococcus	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Cœlosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conferva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyosphærium	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0
Leptothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyngbya	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Microcystis	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0
Oscillaria	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Sirosiphon	0	0	0	0	0	0	0	0	12	0	0	2	0	0	0
Stephanosphæra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulothrix	2	0	0	0	0	0	3	2	0	0	6	14	0	1	0
Fungi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crenothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saprolegnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANIMALS.	3	4	1	0	1	3	5	6	0	2	0	0	4	0	0
Protozoa	3	4	1	0	1	3	5	6	0	2	0	0	4	0	0
Dinobryon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euglena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monas	2	4	0	0	0	2	0	3	0	0	0	0	0	0	0
Paramæcium	0	0	1	0	1	0	3	2	0	2	0	0	1	0	0
Peridinium	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Tintinnus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vorticella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Ciliata	0	0	0	0	0	1	2	0	0	0	0	0	3	0	0
Rhizopoda	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER ORGANISMS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustaceæ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

ALLEGHENY RIVER, (CONT.)

Organisms Per Cubic Centimeter.

Year.	1898.																	
Month.	April.		May.	June.		July.			August.					Sept.				
Day.	5	13	2	3	10	8	25	28	5	11	16	25	30	7	14	21		
PLANTS.	32	52	155	150	101	125	56	43	60	59	60	92	98	21	40	30		
Diatomaceæ	31	49	151	123	86	84	40	37	32	14	32	66	60	19	24	27		
Amphora	0	0	0	5	0	5	0	0	2	0	0	0	2	2	1	0		
Asterionella	1	11	18	9	0	0	0	0	0	0	0	2	0	0	0	0		
Cocconema	0	0	0	0	2	0	0	0	0	0	0	8	0	0	2	0		
Cyclotella	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0		
Cymbella	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0		
Diatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Encyonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Epithemia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Eunotia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Fragilaria	0	0	16	0	0	10	0	0	0	0	0	0	0	0	0	0		
Gomphonema	0	1	2	0	0	2	0	0	4	0	0	4	0	0	0	0		
Melosira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Navicula	8	17	72	56	48	34	32	25	12	12	22	42	46	14	15	21		
Nitzschia	0	0	0	0	0	6	0	0	0	0	0	0	2	0	1	1		
Pleurosigma	0	0	0	3	0	0	2	1	0	0	0	0	2	0	0	0		
Stauroneis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Surirella	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0		
Synedra	20	18	35	50	36	27	6	11	14	2	6	8	6	3	3	5		
Tabellaria	2	2	5	0	0	0	0	0	0	0	4	0	0	0	2	0		
Chlorophyceæ	1	1	3	24	15	41	16	5	28	33	26	20	34	2	13	3		
Arthrodesmus	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0		
Chlorococcus	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0		
Closterium	0	0	1	1	0	0	0	0	0	0	0	0	2	0	0	0		
Cosmarium	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1		
Desmidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Dimorphococcus	0	0	0	0	0	1	0	0	0	0	0	0	6	0	0	0		
Euastrum	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0		
Micrasterias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Palmella	0	0	2	0	5	0	0	0	16	14	6	0	4	0	0	0		
Pandorina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Pediastrum	0	0	0	0	0	3	4	0	0	2	2	2	4	0	0	0		
Protococcus	1	0	0	5	4	25	4	3	12	9	10	12	12	1	4	1		
Raphidium	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0		
Scenedesmus	0	0	0	0	4	7	8	1	0	2	6	4	4	0	7	0		
Sphærozosma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Spirogyra	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0		
Staurastrum	0	0	0	0	2	4	0	0	0	6	2	0	0	1	0	1		
Stigeoclonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Volvox	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		
Cyanophyceæ	0	2	1	3	0	0	0	1	0	12	2	6	4	0	3	0		
Chroococcus	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0		
Cœlosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Conferva	0	0	0	0	0	0	0	0	0	12	2	2	4	0	1	0		
Dictyosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Leptothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Lyngbya	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0		
Microcystis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Oscillaria	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0		
Sirosiphon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Stephanosphæra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Ulothrix	0	2	1	2	0	0	0	0	0	0	0	2	0	0	1	0		
Fungi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Crenothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Saprolegnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
ANIMALS.	3	0	2	2	1	2	2	0	0	12	2	14	0	2	1	1		
Protozoa	3	0	2	2	1	2	2	0	0	12	2	14	0	2	1	1		
Dinobryon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Euglena	1	0	1	0	0	0	0	0	0	2	2	2	0	0	0	0		
Monas	0	0	1	2	0	0	2	0	0	4	0	4	0	0	0	0		
Paramæcium	2	0	0	0	1	2	0	0	0	0	0	0	0	1	0	0		
Peridinium	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0		
Tintinnus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Vorticella	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0		
Other Ciliata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Rhizopoda	0	0	0	0	0	0	0	0	0	4	0	6	0	1	1	1		
OTHER ORGANISMS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Crustaceæ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
Daphnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

	SETTLING BASIN.	EFFLUENT, SAND FILTER No. 1.												
	Organisms Per Cubic Centimeter.													
Year.	1898.				1897.								1898.	
Month.	Aug.	Sept.		Oct.	Aug.	Sept.			Oct.	Nov.			June.	July.
Day.	31	17	27	8	3	4	17	29	8	11	19	29	10	8
PLANTS.	15	115	110	103	0	0	19	4	14	9	0	5	2	0
Diatomaceæ	9	55	51	70	0	0	9	1	8	9	0	3	2	0
Amphora	0	1	0	0	0	0	1	0	0	0	0	0	0	0
Asterionella	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocconema	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epithemia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Melosira	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Navicula	8	45	44	69	0	0	6	1	8	2	0	3	1	0
Nitzschia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synedra	0	5	6	1	0	0	1	0	0	1	0	0	1	0
Tabellaria	1	3	1	0	0	0	1	0	0	0	0	0	0	0
Chlorophyceæ	6	58	53	33	0	0	10	3	6	0	0	2	0	0
Arthrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Closterium	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmidium	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Dimorphococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrasterias	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmella	2	52	49	19	0	0	9	3	5	0	0	2	0	0
Pandorina	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Protococcus	1	0	0	1	0	0	0	0	0	0	0	0	0	0
Raphidium	0	3	0	2	0	0	1	0	1	0	0	0	0	0
Scenedesmus	1	3	4	9	0	0	0	0	0	0	0	0	0	0
Sphærozosma	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirogyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stigeoclonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volvox	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyanophyceæ	0	2	6	0	0	0	0	0	0	0	0	0	0	0
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cœlosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conferva	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyngbya	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microcystis	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oscillaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sirosiphon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanosphæra	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulothrix	0	2	6	0	0	0	0	0	0	0	0	0	0	0
Fungi	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crenothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saprolegnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANIMALS.	1	10	0	1	0	0	2	0	0	0	2	0	0	0
Protozoa	1	10	0	1	0	0	2	0	0	0	2	0	0	0
Dinobryon	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euglena	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monas	1	2	0	1	0	0	2	0	0	0	0	0	0	0
Paramœcium	0	8	0	0	0	0	0	0	0	0	2	0	0	0
Peridinium	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tintinnus	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vorticella	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Ciliata	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhizopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER ORGANISMS.	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustaceæ	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Daphnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0

	EFFLUENT, SAND FILTER, No. 2.											WARREN FILTER.		JEWELL FILTER.	
	Organisms Per Cubic Centimeter.														
Year.	1897.								1898.			1898.		1898.	
Month.	Aug.	Sept.			Oct.	Nov.			April.	June.	July.	April.	May.	April.	June.
Day.	3	4	17	29	8	11	19	29	5	13	10	8	Clear 6	Cloudy 2	Clear 6	Cloudy 3	Cloudy 10
PLANTS.	0	7	16	12	1	0	3	0	0	0	1	0	0	72	0	84	36
Diatomaceæ	0	6	9	4	1	0	3	0	0	0	1	0	0	69	0	56	30
Amphora	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0
Asterionella	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	0
Cocconema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyclotella	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Cymbella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epithemia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melosira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula	0	6	6	4	1	0	0	0	0	0	0	0	0	29	0	24	11
Nitzschia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stauroneis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synedra	0	0	1	0	0	0	3	0	0	0	1	0	0	13	0	30	19
Tabellaria	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Chlorophyceæ	0	1	5	8	0	0	0	0	0	0	0	0	0	0	0	28	6
Arthrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	4
Closterium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Desmidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Euastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrasterias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmella	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Pandorina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Protococcus	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	18	1
Raphidium	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sphærozosma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirogyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stigeoclonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volvox	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyanophyceæ	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cœlosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Conferva	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dictyosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyngbya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microcystis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oscillaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sirosiphon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanosphæra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulothrix	0	0	2	0	0	0	0	0	0	0	0	0	0	3	0	0	0
Fungi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crenothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saprolegnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANIMALS.	1	0	3	0	0	1	0	0	0	0	0	0	0	2	0	1	1
Protozoa	1	0	3	0	0	1	0	0	0	0	0	0	0	2	0	1	1
Dinobryon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euglena	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Monas	0	0	1	0	0	1	0	0	0	0	0	0	0	2	0	0	0
Paramœcium	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peridinium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tintinnus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vorticella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other Ciliata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhizopoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHER ORGANISMS.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Crustaceæ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Daphnia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

	HIGHLAND RESERVOIR, HIGHLAND AVE. MAIN.											HIGHLAND RESERVOIR, BUTLER ST. MAIN.								
	Organisms Per Cubic Centimeter.																			
Year.	1898.											1898.								
Month.	Apr.	July.		August.				September.				July	August.				September.			
Day.	14	16	28	5	12	17	25	1	8	14	21	28	5	12	17	25	1	8	14	21
PLANTS.	34	39	35	28	26	44	62	54	29	28	22	14	36	24	52	48	32	24	22	9
Diatomaceæ	34	7	24	16	12	32	46	30	14	26	15	10	16	12	20	14	14	16	18	4
Amphora	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asterionella	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0
Cocconema	1	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0
Cyclotella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Diatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epithemia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0
Gomphonema	0	2	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Melosira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula	14	5	18	2	12	28	30	14	12	16	15	6	12	12	18	14	10	6	12	0
Nitzschia	0	0	0	0	0	0	4	4	0	4	0	0	0	0	0	0	0	0	2	3
Pleurosigma	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Stauroneis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synedra	12	0	6	10	0	0	10	12	1	4	0	4	4	0	2	0	2	3	0	1
Tabellaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Chlorophyceæ	0	32	11	8	8	10	12	22	10	2	7	3	18	8	30	34	18	7	4	4
Arthrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0
Chlorococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Closterium	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Cosmarium	0	0	0	0	0	0	2	0	0	1	1	0	0	0	0	0	0	1	0	0
Desmidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus	0	0	0	2	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0
Euastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrasterias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmella	0	21	8	0	0	0	0	0	0	0	0	0	18	2	10	20	0	0	0	0
Pandorina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	0	0	0	0	0	0	2	4	0	0	1	1	0	0	0	0	0	1	1	0
Protococcus	0	10	0	4	6	6	2	12	8	1	3	0	0	6	10	8	6	4	0	4
Raphidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus	0	1	3	0	0	2	6	4	1	0	0	1	0	0	6	2	12	0	2	0
Sphærozosma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirogyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	0	0	0	2	0	2	0	2	0	0	1	1	0	0	2	2	0	0	1	0
Stigeoclonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volvox	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyanophyceæ	0	0	0	4	6	2	4	2	5	0	0	1	2	4	2	0	0	1	0	1
Chroococcus	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cœlosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	1
Conferva	0	0	0	4	4	2	2	0	2	0	0	0	2	4	0	0	0	0	0	0
Dictyosphærium	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Leptothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyngbya	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Microcystis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oscillaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sirosiphon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanosphæra	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Ulothrix	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
Fungi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crenothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saprolegnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANIMALS.	1	4	1	0	0	6	2	18	3	4	5	1	4	2	4	10	46	2	0	0
Protozoa	1	4	1	0	0	6	2	18	3	4	5	1	4	2	4	10	46	2	0	0
Dinobryon	0	0	0	0	0	0	0	6	1	0	0	0	0	0	0	0	0	0	0	0
Euglena	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	2	0	1	0	0
Monas	1	0	0	0	0	0	0	0	0	0	3	0	2	0	0	4	0	0	0	0
Paramæcium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Peridinium	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Tintinnus	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
Vorticella	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Other Ciliata	0	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	2	0	0	0
Rhizopoda	0	0	0	0	0	6	2	10	2	1	1	0	0	0	4	4	42	1	0	0
OTHER ORGANISMS.	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Crustaceæ	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Daphina	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0

	HERRON HILL RESERVOIR.									BEDFORD BASIN.								
	Organisms Per Cubic Centimeter.																	
Year.	1898.									1898.								
Month.	July.		August.				September.			July.		August.				September.		
Day.	18	27	5	12	18	25	1	9	14	18	27	5	12	18	25	1	9	14
PLANTS.	75	66	36	46	96	36	34	112	29	68	54	46	68	47	63	28	82	22
Diatomaceæ	15	40	24	4	26	30	10	66	22	14	24	40	30	14	27	4	32	13
Amphora	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asterionella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cocconema	0	0	0	0	0	0	2	4	0	0	0	0	0	0	1	0	0	0
Cyclotella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epithemia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
Fragilaria	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	6	0
Gomphonema	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Melosira	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Navicula	4	20	12	4	24	28	6	36	14	14	14	16	16	6	13	4	16	6
Nitzschia	0	2	0	0	0	0	0	0	4	0	0	18	6	8	12	0	7	6
Pleurosigma	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0
Stauroneis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synedra	10	18	4	0	2	2	2	4	4	0	10	4	8	0	1	0	1	0
Tabellaria	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorophyceæ	60	26	10	36	68	6	18	24	5	52	25	4	38	25	24	16	30	5
Arthrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Closterium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cosmarium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Desmidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Micrasterias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmella	35	0	2	18	54	4	0	0	0	30	6	2	14	3	0	0	0	0
Pandorina	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pediastrum	2	0	0	4	0	0	2	0	0	0	0	0	0	2	0	2	1	0
Protococcus	19	24	6	10	12	0	16	18	5	22	15	2	18	15	16	10	23	5
Raphidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
Scenedesmus	1	0	0	0	2	0	0	4	0	0	4	0	4	3	5	2	2	0
Sphærozosma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirogyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	1	2	2	2	0	2	0	2	0	0	0	0	2	0	0	2	0	0
Stigeoclonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Volvox	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Cyanophyceæ	0	0	2	6	2	0	6	2	2	2	5	2	0	8	12	8	20	4
Chroococcus	0	0	0	2	0	0	0	0	0	2	5	0	0	0	1	0	2	2
Cœlosphærium	0	0	2	0	2	0	0	2	1	0	0	0	0	1	1	0	0	0
Conferva	0	0	0	2	0	0	6	0	0	0	0	2	0	3	8	8	18	2
Dictyosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lyngbya	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Microcystis	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Oscillaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sirosiphon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanosphæra	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0
Ulothrix	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Fungi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crenothrix	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Saprolegnia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ANIMALS.	5	32	4	10	24	4	16	10	37	324	1256	376	40	8	7	16	19	3
Protozoa	5	32	4	10	24	4	16	10	37	324	1256	376	40	8	7	16	19	3
Dinobryon	0	24	0	0	0	0	0	0	0	306	1252	374	26	1	0	0	0	0
Euglena	2	2	0	0	2	2	2	0	0	10	1	0	4	0	3	6	18	0
Monas	1	6	0	0	10	0	0	2	0	0	1	0	10	2	0	2	1	1
Paramæcium	0	0	0	0	10	0	0	2	1	4	1	0	0	1	0	0	0	0
Peridinium	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0
Tintinnus	0	0	0	8	0	0	0	0	0	0	0	0	0	1	2	0	0	0
Vorticella	0	0	0	0	0	0	2	0	33	0	0	0	0	0	1	0	0	0
Other Ciliata	2	0	4	2	0	2	0	0	0	4	1	2	0	2	0	0	0	0
Rhizopoda	0	0	0	0	2	0	12	6	3	0	0	0	0	0	1	6	0	2
OTHER ORGANISMS.	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Crustaceæ	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Daphnia	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0

	SOUTH SIDE RESERVOIR.								WILKINSBURG RESERVOIR.							
	Organisms Per Cubic Centimeter.															
Year.	1898.								1898.							
Month.	July.		August.			September.			July.		August.			September.		
Day.	16	25	5	18	25	1	9	14	18	27	13	18	26	1	9	14
PLANTS.	81	30	58	18	34	4	21	6	52	94	22	90	31	54	388	1212
Diatomaceæ	11	2	12	8	22	2	6	2	24	76	8	11	7	31	206	1163
Amphora	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Asterionella	0	0	0	0	0	0	0	0	0	0	0	1	0	30	193	1155
Cocconema	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0
Cyclotella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cymbella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diatoma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Encyonema	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Epithemia	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eunotia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fragilaria	0	0	0	0	0	0	0	0	0	71	0	0	0	0	6	0
Gomphonema	1	0	0	0	2	0	0	0	0	0	2	1	0	0	0	0
Melosira	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0
Navicula	5	2	10	6	14	2	6	1	2	5	6	4	2	1	7	4
Nitzschia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleurosigma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Stauroneis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanodiscus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Surirella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Synedra	2	0	0	2	6	0	0	0	14	0	0	5	1	0	0	1
Tabellaria	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	2
Chlorophyceæ	63	24	44	10	12	2	12	1	21	3	14	65	13	6	4	30
Arthrodesmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chlorococcus	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Closterium	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Cosmarium	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	26
Desmidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dimorphococcus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euastrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Micrasterias	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Palmella	40	0	40	10	10	0	0	0	17	0	8	39	0	0	0	0
Pandorina	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Pediastrum	5	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Protococcus	10	14	4	0	0	2	12	1	0	0	2	23	10	3	3	2
Raphidium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Scenedesmus	0	6	0	0	0	0	0	0	1	1	0	0	0	1	1	1
Sphærozosma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spirogyra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Staurastrum	1	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Stigeoclonium	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Volvox	0	0	0	0	0	0	0	0	1	1	2	1	2	1	0	1
Cyanophyceæ	7	4	2	0	0	0	2	3	3	14	0	6	5	9	175	16
Chroococcus	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
Cœlosphærium	0	0	0	0	0	0	0	0	0	12	0	6	0	0	1	15
Conferva	0	0	0	0	0	0	1	2	2	1	0	0	0	9	174	0
Dictyosphærium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Leptothrix	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lyngbya	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0
Microcystis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oscillaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sirosiphon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stephanosphæra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulothrix	7	4	0	0	0	0	1	1	0	0	0	0	0	0	0	1
Fungi	0	0	0	0	0	0	1	0	4	1	0	8	6	8	3	3
Crenothrix	0	0	0	0	0	0	1	0	4	0	0	8	6	8		3
Saprolegnia	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
ANIMALS.	5	0	2	4	4	6	8	0	1	0	0	15	34	217	8	5
Protozoa	5	0	2	4	4	6	8	0	1	0	0	15	34	217	8	5
Dinobryon	0	0	0	0	0	0	1	0	0	0	0	0	12	183	0	0
Euglena	0	0	0	0	0	0	1	0	0	0	0	0	1	17	0	1
Monas	0	0	2	0	0	2	6	0	0	0	0	14	0	0	1	2
Paramœcium	1	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0
Peridinium	0	0	0	0	0	0	0	0	0	0	0	0	0	10	6	2
Tintinnus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vorticella	4	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Other Ciliata	0	0	0	0	0	0	0	0	1	0	0	1	4	0	0	0
Rhizopoda	0	0	0	2	4	4	0	0	0	0	0	0	15	7	0	0
OTHER ORGANISMS.	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1
Crustaceæ	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1
Daphnia	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	1

APPENDIX No. 5.

REPORT UPON DRIVEN WELL SUPPLY.

E. M. BIGELOW, ESQ.

Director of Department of Public Works.

DEAR SIR:

In accordance with your instructions; in order to ascertain whether it was possible to secure a supply of ground water at our Brilliant Pumping Station, in sufficient quantities and of proper quality for supplying the city by means of driven wells, I beg to report that the contract was let for driving a six-inch well, that is, five and five-eighths inches, inside, and the work was commenced early in May. We located this well at the south corner of the building, and about fifty feet from the river's edge. The accompanying blue print[1] will show you the character of the materials through which the well went, and also the amount of water secured at the different depths. You will notice by the accompanying analyses[2] that the water in the sand stone was of a good quality, and by reference to the blue print[1] you will find that the quantity was such that it would take something like six hundred wells, to give us our present supply of water, assuming that they would all have the same flow as this one well. which is very doubtful. Although, as I stated above, the water is of good quality, you will notice it is very hard and could not be used for steam making purposes, and would probably be disagreeable for ordinary washing. Farther down, the quantity of water remained about the same, but the character of it became worse when the slate was struck. It carried a large quantity of gas and was very disagreeable to the taste and smell. At the extreme bottom it was quite salty, and the result of the experiment seems to be that the idea of securing a supply of water in that neighborhood in this manner is entirely impracticable.

Yours respectfully,

A. B. SHEPHERD,
Superintendent,
Bureau of Water Supply and Distribution.

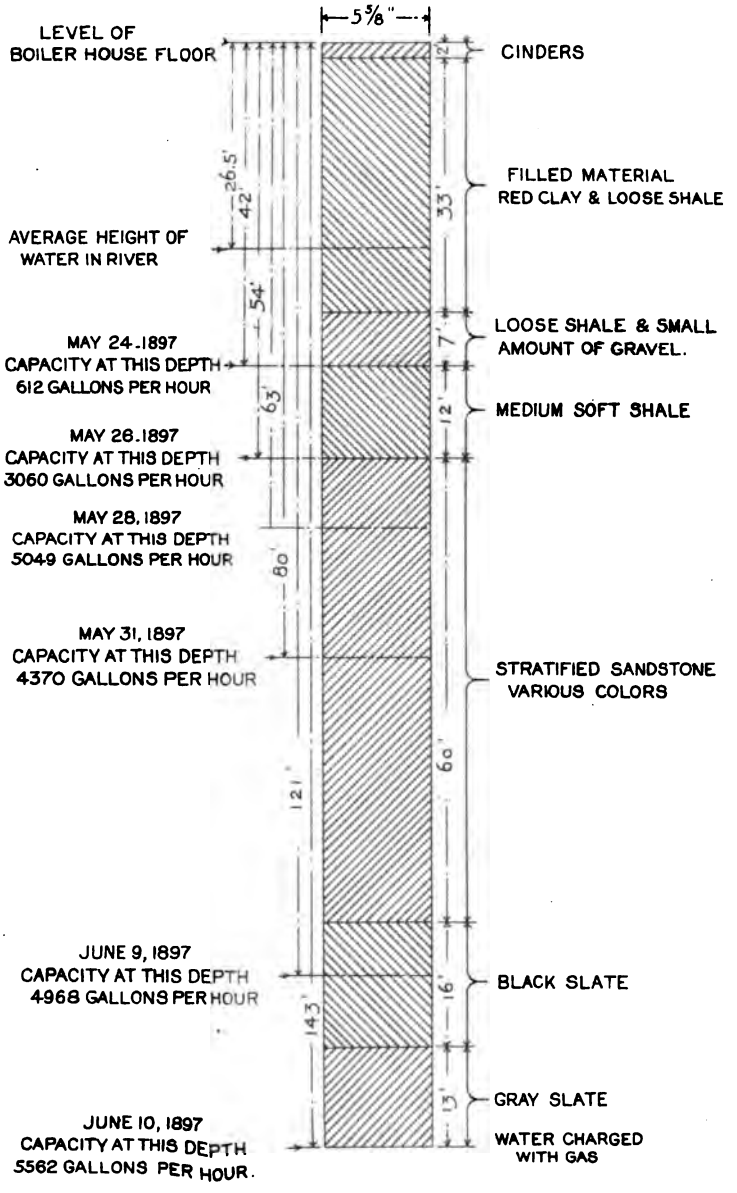
July 16, 1897.

[1] Reproduction of the blue print given opposite this page.

[2] Results of analyses will be found in Appendix No. 2, Page 316.

Plate No. 21.

TEST WELL
AT
BRILLIANT PUMPING STATION



APPENDIX No. 6.

FINANCIAL STATEMENT.

Appropriation No. 46,—Dated February 1, 1899.

CLASSIFICATION OF EXPENDITURES.

Consultation Salaries	$ 5,249 93	
Salaries of Office and Laboratory Force	13,188 08	
Wages of Filter Attendants, Mechanics and Laborers	5,144 81	
Furniture, Apparatus and Fixtures	697 57	
Material and Supplies for Office and Laboratory	1,323 70	
" " " Sand Filters	1,546 59	
" " " Filter Building and Filters within	2,987 61	
" " " Boiler Experiment	1,241 39	
Surveys	923 78	
Office and Traveling Expenses of Employees	1,716 54	
Total		$34,020 00

DISTRIBUTION OF EXPENDITURES.

Construction and Installation.

Office and Laboratory	$1,100 57	
Sand Filters	2,771 13	
Filter Building	815 33	
Warren Filter	1,206 46	
Jewell "	1,305 88	
Worms Tile Filter	676 90	
Boiler Experiment	693 71	
Total	$8,569 98	

Maintenance and Operation.

Engineering Administration	$12,612 56	
Analyses of River, Crib, and Tap Waters	1,563 82	
Miscellaneous Analyses	290 26	
Species and Micro-Organism Work	409 00	
Attendance and Analyses, Sand Filters	2,769 85	
" " Warren Filter	1,810 14	
" " Jewell "	1,613 02	
" " Worms Tile Filter	1,198 12	
Studies for Filter Sites	749 61	
Gravity Supply Study	437 53	
Boiler Experiment	1,199 54	
Sanitary Investigations	421 32	
Miscellaneous Studies	375 25	
Total	$25,450 02	
Total Expenditures		$34,020 00

In addition to this amount, there has been expended by the Bureau of Water Supply and Distribution, the following sums :—

Drilling Test Well at Brilliant	$ 282 56	
Laboratory Fixtures and Apparatus	1,012 87	
Supplies for Filter Building and Filters within	1,421 21	
Teaming, Expressage, Etc.	139 74	
Labor at Brilliant	1,868 80	
Total		$ 4,725 18

FINANCIAL STATEMENT—Continued.

There are also unpaid bills to the account of appropriation No. 46, as follows:—

CLASSIFICATION.

Consultation Salaries	$ 1,970 00	
Boiler Experiment	145 25	
Traveling Expenses of Employees	150 92	
Total		$ 2,266 17

DISTRIBUTION.

Construction and Installation.

Boiler Experiment	$ 145 25	
Total	$ 145 25	

Maintenance and Operation.

Gravity Supply Study	$ 1,539 57	
Sanitary Investigations	581 35	
Total	$ 2,120 92	
Total Amount Unpaid		$ 2,266 17

INDEX.

PAGE.

Absorption of alumina, *see* Mechanical filters, *see also* Sulphate of alumina.
" " oxygen, *see* Dissolved oxygen.
Acidity of media, *see* Media.
Acknowledgment of courtesies..... 116
Agar, litmus lactose and nutrient glycerine..... 334
" used for plating..... 334
" Wurtz litmus..... 328
Agreements with filter companies..... 111
Agitator, *see* Jewell and Warren Filters.
Agitating, surface of sand, *see* Jewell Filter, trailing.
Air valves, *see* Indian Creek, conduit.
Albuminoid ammonia, *see* Ammonia.
Algæ, found in samples of waters..... 349, 352
Alkalinity, method of determining..... 230
" of media, *see* Media
" of samples of waters..... 238
Allegheny City tap, analyses of samples from..... 282
" " water works, description of, and samples from..... 278
Allegheny River:—
Analyses of samples from..... 237
At Brilliant, analyses of samples from..... 234
" Etna, " " " " 299
" Hulton, " " " " 285
" Kittanning, " " " " 321
" Millvale, " " " " 305
" Montrose, " " " " 278
" Sharpsburg, " " " " 298
" Wildwood, " " " " 292
Character of water supply derived from..... 16
Drainage area of..... 30
Intake at Brilliant..... 238
List of cities and towns upon..... 30
Rapidity of flow and lack of self-purification..... 18
Samples from, analyses of..... 237
Sanitary condition of supply drawn from..... 30
Special samples from..... 243
Allegheny River Water:—
Alkalinity of..... 57
Amount of calcium carbonate in..... 57
Analyses of samples of..... 237
Bacteria in, daily results..... 127, 172, 194, 207
" " monthly averages..... 39
" species found in..... 346
Calcium carbonate in..... 57, 63
Character of..... 232

PAGE.
Allegheny River Water,—*Con:*—
Composition of ... 33
" " before and after settling and after filtration ... 39, 43
Healthfulness of ... 27
Lime in, *see* Calcium carbonate
Micro-organisms found in ... 352
Mineral analysis of ... 243
Samples of, analyses of ... 237
Special samples of ... 243
Species of bacteria found in ... 346
Allegheny water works, *see* Allegheny City water works, *see also* Montrose.
Alum, Alumina, *see* Sulphate of alumina.
Alumina, method of determining ... 231
Aluminum foil, used in determining nitrates ... 228
American filters, *see* Mechanical filters.
" Public Health Association, reference to ... 344
" system of filtration, *see* Mechanical filters.
Ammonia, in samples ... 237
" method of determining ... 226
Analyses, cost of ... 361
" of samples ... 237
" sand ... 121, 157, 183
Analysis, Committee on Water ... 1
Animals, list of, found in samples ... 352
Annual charges for gravity supply and filtration ... 84
see also Charges, Depreciation, Interest and Sinking fund.
Antwerp, visit to ... 3
Appendices to report of Resident Engineer, list of ... 117
" title page of ... 221
Aqueduct, *see* Indian Creek.
Area, *see* Drainage area.
" of sand surface, *see* Jewell, Sand and Warren Filters.
Arrangements with filter companies ... 111
Asbestos, use of with sand filters ... 70, 115
Assistants employed, list of ... 119
Asterionella, found in samples ... 350, 352
Atlanta, use of meters in ... 77
Atmospheric dust, as a source of typhoid fever ... 12
Attendants, list of filter ... 117
Autoclave, use of ... 335
Auxiliary supply, reference to in report of Consulting Engineer ... 71
" " report of Commission upon ... 6
Bacilli, list of ... 327
Bacillus, *coli communis*, tests for ... 348
" *prodigiosus*, test with ... 345
Bacteria, growth in underdrains ... 60
in effluents, *see also* Jewell, Sand, Warren, and Worms Tile Filters.
" method of examination for ... 331
" numbers of, in samples ... 237
" species of, found in samples ... 344
Bacterial efficiency, *see* Jewell, Sand, Warren, and Worms Tile Filters, *see also* Cribs

PAGE.
Bacteriological analyses, reference to 38
" and Microscopal Investigations, report upon 325, 331
Bacteriologist, reference to 2, 16, 21, 38, 110, 116
" report of, Dr. Eugene Wasdin 325
" " " Wm. R. Copeland 331
Barium chloride, used in determining sulphuric acid 230
Basin, *see* Sedimentation, Settling, and Storage Basins.
see also Indian Creek and Squaw Run
Bay City, use of meters in 77
Beck's Run, analysis of sample of Monongahela River from 319
Bedford Basin, bacterial examination of samples from 330
" " micro-organisms found in samples from 357
Bennett Water Company, *see* Millvale.
Berkefeld Filter Company, proposition from 112
see also Domestic and Household filters.
Berlin, visit to 3
" use of meters in 76
Bigelow, E. M., reference to 3, 109, 112
" " report to, on Driven Well Supply 360
Biggs, Geo. W., Jr., reference to 116
Bills unpaid 361
Biological laboratory 110, 114, 323, 327
Biologist, *see* Bacteriologist.
Blow-offs, *see* Indian Creek, conduit.
Boilers, estimated cost of 65
Boilers, experimental:—
Analyses of scales 217
" " water 314
Burners under 216
Calcium in scale 217
Comparison of effect of different waters 63
Condition of and conclusions about 219
Cost of experiments 361
Dimensions of 216
Expert's opinion about condition of 218
Gas supply 216
Injectors 217
Lime, *see* Calcium
Oil Well Supply Company, reference to 115, 216
" " report by, on condition of 218
Reference to 63
Scale 217
Supply of water 216
Bonds, issue of, recommended 7
Boston, Mass., rainfall near 92
" " typhoid fever death rate in 11
Bottles, for collection of samples 225
Bremen, visit to 3
Brilliant, driven well at, analyses of samples from 316
" reference to experimental filter plant at 141

PAGE.
Brilliant, samples from Allegheny River at 237
Brockton, use of meters in 77
Brown, Wm. R., City Engineer, reference to 112
Bureau of Health, laboratory of 110, 327, 333
" " Water Supply and Distribution, money expended by 361
Burners, *see* Boilers, experimental.
Butler Street Main, *see* Highland Park Reservoir.

Calcium carbonate, action of, in water on sulphate of alumina 57
" " in sands, *see* Chemical analyses of.
Capacity of basin, *see* Jewell, Sand, Warren and Worms Tile Filters, *see also* Indian Creek and Squaw Run.
Castleman's River, analyses of samples from 323
" " as a gravity source 80
Carbonate of lime, *see* Calcium carbonate.
Carbonate of magnesium, *see* Boilers, experimental, scale.
Caustic permanganate, used in ammonia determinations 226
Celery, as a source of typhoid fever 12
Census of Pittsburgh, reference to 22
Chains, *see* Jewell Filter.
Chairmen of Commission and of Committees 1
Channels in sand, *see* Sand filters.
Chapters to report of Resident Engineer, list of 117
Character of, Allegheny River water 30
" " Monongahela River water 32
" " present water supply 3, 30
" " water supplied to South Side 15, 31, 32
Charges, annual, for gravity supply and filtration 84
see also Annual charges, Depreciation, Interest and Sinking fund.
Charts, *see* Diagrams.
Cheat River, as a gravity source 80
Chemical analyses, methods of 225
" " reference to 38, 109
Chemical analyses of, Allegheny and Monongahela Rivers 33
see also Allegheny and Monongahela Rivers, composition of
" " effluents, filter effluents, *see* Jewell, Sand, Warren and Worms Tile Filters.
" " river sands 120, 121
" " river waters 33
" " samples 233
" " sand in sand filters 122
" " scale 217
Chemist, reference to 2, 38, 109, 116
" report of, methods of chemical analyses and discussion of results 223
" " " reference to 109
Cherry Alley, analyses of samples from 244
Chestnut Ridge, reference to 89, 98
Chezy formula, reference to 100
Chlorine, cause of, in river waters 233
" in samples of water 237
" method of determining 228

PAGE.
Chlorophyceæ, list of, found in samples 352
Cincinnati, Ohio, visit to 2
City Engineer, reference to 112
City samples, analyses of miscellaneous 318
" " bacterial examination of 325
City taps, analyses of samples from, *see* Allegheny, Etna, Millvale, Sewickley, Sharpsburg, South Side, Verona and Wilkinsburg.
City water, bacterial examination of 325
Cities, American, use of water in 95
" and towns, list of, upon the Allegheny River 30
" " " " " " " Monongahela River 32
" using meter system 76
" using sand filters 5
" visited 2, 3
Clarification, amount of sulphate of alumina required to produce 55
Clay, *see* Turbidity.
Cleaning of filters, *see* Jewell, Sand, Warren, and Worms Tile Filters.
Clearness of effluents, comparison of, with sand and mechanical filtration 61
see also Jewell, Sand, Warren, and Worms Tile Filters.
Coagulant, absorption of, by muddy waters 54
" explanation of use of 36
" use of other, than sulphate of alumina 70
" variation in rate of application of, *see* Jewell and Warren Filters.
see also Jewell, Mechanical, Warren, and Worms Tile Filters; *also* Iron chloride and Sulphate of alumina.
Coagulant pump, *see* Jewell and Warren Filters.
Coagulation, absorption of sulphate of alumina without producing 54
Coal, *see* Indian Creek.
Coal lands, difficulty in crossing, *see* Indian Creek, conduit.
Coefficient of conduit discharge 100
see Indian Creek, tunnel and conduit.
see also Uniformity coefficient.
Coli communis, Bacillus, tests for 348
Collection of samples 225
Colonies developed by growth of different days 338, 339
" " in media of different reactions 340
Colon group of bacteria 328
Color, in river water due to what 62, 232
" method of determining 223
" of samples of waters 237
" of waters used in eastern cities 62
" removed, comparison of, by sand and mechanical filters 62, 232
Commission, duties, organization and report of 1
" resolution creating iii
" visits by 2, 116
Committees, list of 1
Companies, *see* Filter companies.
Comparative cost of, gravity supply and filtration 82
" " " sand and mechanical filters 4
Composition of Allegheny and Monongahela Rivers 33
" " effluents, *see* Jewell, Sand, Warren, and Worms Tile Filters.

PAGE.
Comte Fils gelatine 334
Conclusions, of Commission 3, 7
" of Consulting Engineer 85
" of Prof. Wm. T. Sedgwick 23
" upon gravity supply 105
Conditions under which experiments were conducted 111
Conduit, *see* Gravity supply, Indian Creek and Laurel Hill Creek, conduit.
see also Cost and Estimates.
Conemaugh River, as a gravity source 80
Conferva, found in samples 349, 352
Confluence, rainfall at 92
Connellsville, reference to 80
Constituents, *see* Allegheny and Monongahela Rivers and Settled water, composition of.
see also Jewell, Sand, Warren, and Worms Tile Filters; *also* Chemical analyses.
Construction of filters, cost of 64
" " " " " for experiments 361
Consulting Engineer, conclusions and recommendations of 85
" " reference to 2
" " report of 27
Consumption of water, from Indian Creek 94
" " " in American cities 95
" " " in Pittsburgh 73, 94
" " " study of 113
see also Water, amount required.
Contagion of typhoid fever 13
Contagious diseases, *see* Typhoid fever
Contamination, indication of fæcal, in city water 329, 348
Contents, table of ..... v.
Continental Filter Company, invitation sent to 111
Contingencies, estimate for, in cost of filters 65
Copeland, Wm. R., reference to 2, 16, 21, 38, 110, 116
" " report of 331
Cornell Dam, reference to 81, 97
Corrosion, *see* Boilers, experimental.
Cost, comparative, of sand and mechanical filtration 4
" comparison between gravity supply and filtration 82
" of construction of filters, itemized 65
" of experiments 361
" of gravity supply from Indian Creek 82
" of installing meter system 78
" of maintenance of filters 66
" of sand filtration plant recommended for Pittsburgh 6
see Indian Creek and Laurel Hill Creek, *also* Jewell, Sand, Warren, and Worms Tile Filters, cost of.
Coster, Wm., of Coster & Riddle, reference to 109
Coster & Riddle, analyses of samples from laboratory of 244
" " laboratory of 109
Counting bacteria, *see* Bacteria, method of examination for.
Covered filters, necessity for, in Pittsburgh 44

PAGE.
Covington, Ky., visit to 2
Cracks in concrete, *see* Sand filters.
Creek, *see* Indian Creek, *also* Laurel Hill Creek.
Crenothrix, found in samples 350
Cribs, filter, efficiency of 237
" " reference to 70
see also Etna, Hulton, Millvale, Montrose, Sewickley, Sharpsburg, and Wildwood.
Crustaceæ, found in samples 352
Culture, Koch's plate method 334
Cumberland Manufacturing Company, agreement with 111
see also New York Filter Manufacturing Company, *also* Mechanical filters, and Warren Filter.
Cyanophyceæ, list of, found in samples 352

Dairies, analyses of well and spring waters from 319
Dam, *see* Sand filters, storage reservoir.
" Storage reservoir for river water.
" *also*, Indian Creek, Laurel Hill Creek, and Squaw Run.
Damages, *see* Indian Creek.
Date of, commencing and closing experiments 109
" " first starting filters 111, 112, 119
" " visits, *see* Visits.
Davison, Wilkins & Davison, reference to 113
Dayton, use of meters in 77
Deaths from, contagious diseases, *see* Typhoid fever.
" " typhoid Fever 11
Depreciation charges, for gravity supply 83, 104
" " for filters 66
" " for pumping machinery, ... 66, 83
see Charges, *also* Sinking fund.
Depth of sand in filters, *see* Jewell, Sand, and Warren Filters.
Des Moines, use of meters in 77
Diagrams, list of ..... ix.
Diatomaceæ, list of, found in samples 350, 352
Dinobryon, found in samples 350, 352
Director of Public Works, reference to 3, 109, 112
" " " report to, on Driven Well Supply 306
Discussion of, results of chemical analyses 232
Dishes, *see* Petri dishes.
Dissolved oxygen, in effluents from sand filters 123
" " method of determining 232
Dissolved solids, *see* Solids, *see also* Suspended matter.
Distribution system for auxiliary supply 71
" of typhoid fever in Pittsburgh 22
Domestic, or Household filters, reference to 71
see also Berkefeld Filter.
" use of water 74
Donegal, on Indian Creek water-shed, population of 90
Drainage area, *see* Allegheny and Monogahela Rivers, *see also* Indian and Laurel Hill Creeks.

PAGE.
Drinking water in mills 23
see also Auxiliary supply.
Driven well, analyses of samples from 316
" " cost of drilling 361
" " report upon supply from 360
Durability of sand and mechanical filters 5
Dust, atmospheric, as a source of typhoid fever 12
Duties of Commission 1

Effective size of sand, used in Jewell Filter 183
" " " " " Sand Filters 121
" " " " " Warren Filter 517
Efficiency, bacterial, of sand filters, after scraping 124
" " " " " effect of cold weather on 44
" of filtration, *see* Jewell, Sand, Warren, and Worms Tile Filters.
" of sand and mechanical filtration 4, 60
Effluents, *see* Cribs, *see also* Jewell, Mechanical, Sand, Warren, and Worms Tile Filters
" of sand filters used in laboratory 115
Elsner's gelatine 327
Engineer, City, reference to 112
" Consulting, reference to 2
" Resident, reference to ..... ; 2, 7, 38
Engineering, estimate for, in cost of filters 65
Engineers employed by Commission 2
" United States, reference to 19
English filters, *see* European and Sand filters, *see also* Berlin, Hamburg, and London.

Epidemics of typhoid fever, study of 113
" " " " traced to milk supply 14
Estimates, of Berkefeld Filter Company 112
" of filters for Pittsburgh, ... 65
see also Costs.

Etna, analyses of samples from 299
" crib, analyses of samples from 301
" " description of 299
" tap water, analyses of samples of 304
European filters, reference to covered 44
" " visited 2, 3
see Sand filters, *see also* Berlin, Hamburg, and London.
Evaporation, residue on, method of determining 229
Exhibits, list of, reports to accompany Commission's Report 7
Expenditures, list of 361
Experimental boilers, *see* Boilers, experimental.
" filter plant, description of 114
" filters, results secured with 38
Experiments upon filtration, data to be received by 37
" " " results secured by 38
Experts, list of, employed by Commission 2
Fall River, use of meters in 77
Fayette County, Pa., rainfall in 92

PAGE.
Fayette County, Pa., reference to 90, 112
see Gravity Supply, *see also* Indian Creek.
Fermentation germs 328
" of sugar 327
Ferric oxide, Ferrous oxide, *see* Iron oxide
Filling from below, *see* Sand filters.
Filter building, description of 115
Filter companies, invitations sent to 110
" " list of 111
Filter plant experimental, description of, *see* Experimental filter plant.
Filtered solids, method of determining 229
Filtering materials, *see* Jewell, Mechanical, Sand, Warren, and Worms Tile Filters
Filters, covered, necessity for 44
" results secured with experimental 38
see Berkefeld, European, Home, Household, Jewell, Mechanical, Sand, Warren, and Worms Tile Filters, *see also* Cumberland Manufacturing Company, Morrison-Jewell Filtration Company and New York Filter Manufacturing Company.
Filtration, annual charges for, *see* Annual charges.
" comparison of mechanical and sand 65
" cost of 4, 65
" cost of, compared with cost of gravity supply 82
" effect of 3
" experiments upon 37
" methods of, investigated 28
" nature of 36
Filtration Commission, *see* Commission.
Filtration cribs or galleries, reference to 70
Filtration plant, advisability of establishing 4
" " inspection of 2, 3
Financial statement 361
Fischer, Director, reference to 112
" Tile System, *see* Worms Tile Filter.
Fixture rates, changing to meter rates 77
Flat-lands, survey of 112
Flies as a source of typhoid fever 12
Flinn, Hon. Wm., reference to 3, 112
Fogg, C. E., of Jamison & Fogg, reference to 113
Food, infected uncooked, as a source of typhoid fever 12
Fortune, W. W., reference to 112
Frankstown Avenue, analysis of tap water from 319
Free ammonia, *see* Ammonia.
Freezing of surface of sand filters 120
Fruits, as a source of typhoid fever 12
Fuller, G. W., reference to methods of bacterial examinations 334, 339
" " " report on Louisville experiments 50, 54, 58, 70
Fungi, list of, found in samples 352
Gagings, *see* Indian Creek.
Galleries, filtration, use of 70
see also Cribs.
Garfield Tank, bacterial examinations of samples from 33

PAGE.
Gas, natural, sale of, by meter system 74
Gate chamber, analysis of samples from 246
" " micro-organisms found in samples from 349
" " special samples from 249
" " species of bacteria found in samples from 346
Gelatine, Comte Fils 334
" growth for different days on 338
" liquefaction of 338
" nutrient, method of sterilizing 335
" used in making media 334
General Information, Committee on 1
" remarks, in Resident Engineer's Report 116
German filters, reference to periods between scrapings 47
Glunt spring, analyses of water from 320
Gravity supply 80
" " annual charges for 84
" " comparison between, and filtration 82
" " conclusions upon 105
" " cost of 82
" " study, cost of 361
" " reference to 29, 113
" " report upon, by Consulting Engineer 80
" " " " by Emil Kuichling, C. E. 87
see also Indian Creek and Laurel Hill Creek.
Greensburg, Pa., rainfall at 92
Greiss' method of determining nitrites, reference to 227
Gutters, vertical iron, *see* Warren Filter.
Hamburg, Germany, visit to 3
Hardness, method of determining 230
" of effluents, comparison of mechanical and sand filtration 62
" of samples collected 237
" permanent, compared to temporary 62
Hazen, Allen, C. E., reference to 2, 8
" " " report of 25
Hazen and White method 327
Head, *see* Loss of head.
Head on filters, *see* Sand filters.
Health, Bureau of, *see* Bureau of Health.
" character of present water supply in its relation to public 3
Healthfulness of Allegheny River water 27
Height of water in filters, *see* Jewell, Sand, and Warren Filters.
Herron Hill Laboratory, reference to 190
" " Reservoir, bacterial examination of samples from 330
" " " micro-organisms found in samples from 357
Herr's Island, reference to 278
Highland Reservoir, *also* Highland Park Reservoir.
" " bacterial examination of samples from 330
" " micro-organisms found in samples from 356
" " reference to end of Indian Creek conduit 89
Hoboken, use of meters in 77
Holland, Dr. W. J., reference to 3, 114, 327

PAGE.
Holliday, Geo. L., reference to 1
Home filters, Household filters, reference to 71
see also Berkefeld Filter.
Howe spring, analyses of samples from 316
Hudson River, reference to 28
Hulton, analyses of samples from 285
" crib, description of 285
" " analyses of samples from 287
see also Verona.
Ice on filters, *see* Sand filters.
Ice supply, reference to 3
" " as a source of typhoid fever 13
Ignition, *see* Loss on ignition
Incrusting constituents 63
see also Boilers, experimental.
Indian Creek:—
Analyses of samples from 321
As a gravity source of supply 80
Charges, annual 83, 104
Coal land, difficulties with 82, 101
Comparison of cost of supply from, with filtration 82
Conclusions upon 105
Conduit, blow-offs on 101
" capacity of 95, 99
" coal workings under 101
" coefficient and slope of 100
" cost of 102
" length of 81
" reservoirs, intermediate 101
" size of 100
" route of 99
" spillways and structures on 101
" subsidence 101
" valves and waste weirs on 101
Cost of work 82, 102
Dam, cost of 81, 96, 102
" elevation of 96
" increase of, to store Laurel Hill Creek 93
" masonry in 97
Depreciation charges 83, 104
Description of source of supply 89
Estimates for and cost of engineering 102
Gagings of 91
Interest charges 104, 105
Maintenance, cost of 103
Mill privileges upon 97
Operations, cost of 103
Pipe line, *see* Conduit
Pollution, prevention of 97
Quality of water 81
Quantity of water available 91

Indian Creek,—*Con.*:— PAGE.
Records of rainfall ... 91, 92
Report upon, by Emil Kuichling, C. E. ... 97
Reservoir, capacity of ... 81
" cost of ... 102
" description of ... 89, 96
Resler's Run ... 89, 90
Roads rebuilt ... 97
Sinking fund charges ... 83, 103
Steel pipe, *see* Conduit.
Structures, life of ... 104
Tunnel, capacity and size of ... 98
" cost of ... 102
" route of ... 98
" shafts on and time required for building ... 99
" slope of ... 99
" White Run, at end of ... 98
Water-shed, description of ... 90
" drainage area of ... 89
" population and towns upon ... 90
" rainfall upon ... 91
Western Water Company records ... 91
see also Gravity supply.
Indian Head on Indian Creek water-shed ... 90
Indicator, rate of flow, *see* Sand and Worms Tile Filters.
Infected uncooked food, as a source of typhoid fever ... 12
Infection, secondary ... 3, 13
Infectious diseases, *see* Typhoid fever.
Information, General, Committee on ... 1
Inspection of, filtration plants ... 2, 3
" " rivers and water-sheds ... 3
Installation, cost of, for experiments ... 361
Intake, estimated cost of ... 65
see also Allegheny and Monongahela Rivers, *also* Etna, Hulton, Millvale, Montrose, Sewickley, and Wildwood.
Interest charges, on cost of filters ... 66
" " on cost of gravity supply ... 83
Intestinal organisms ... 327
Investigations, pollution, reference to ... 3, 114
" scope of ... 1
Iron, in samples ... 237
" in sand, *see* Chemical analyses of.
" method of determining ... 231
" oxide ... 159, 202

Jackson, D. D., reference to ... 349
Jamison & Fogg, reference to ... 113
Jewell Filter :—
Agitator ... 182
Alkalinity of effluent ... 185
Alumina, *see* Coagulant.
Area of sand surface ... 180

Jewell Filter,—*Con.*:— PAGE.
Bacteria, in effluent 184, 194
" " at times of washing 188
" in raw water 184, 194
" " settled water 194
Bacterial efficiency of, after cleansing 191
" " " trailing 190
" " " washing 187
" " without coagulant 192
Butterfly valve 180
Cement around screens 181
Chemical analyses of effluent 262
Cleansing 181, 183, 191
Coagulant, composition of 159
" effect of different quantities of 191
" method of application of 180
" used 184
" variation in application of 183
Conduits, area of collecting 181
Cost of experiments 361
Controller, *see* Regulator.
Daily results 193
Description 180
Diagram, *see* Plan, *see* Elevation.
Effluent, analyses of 262
" bacteria in 184, 194
Elevation 182
Experiments, cost of 361
Exit area 181
Float 180
Head, loss of 189
Hours in operation 193
Meters 181
Micro-organisms found in effluent 355
Monthly results, table of 193
Operations 182
Orifice plate in regulator 181
Plan 182
Rakes 181, 182
Rate of filtration, variation in 183
Records, monthly 192
Regulator for inlet 180
" in effluent pipe 181
Results, tabulation of 193
Sand, analyses of 183
" area and depth of 180
" removed and restored 183
Settled water, samples of 264
Settling basin 180
Screens, area of 181
Soda ash, used to cleanse 191
Solution, *see* Coagulant.

Jewell Filter,—*Con.*:— PAGE.
Special experiments, using different quantities of coagulant ... 191
Sulphate of alumina, *see* Coagulant.
Summary of monthly results ... 40
Surface area ... 180
Time in operation ... 191
Times of washing ... 193
Trailing, effects of ... 189
Turbidity, observations of ... 193
Washing, bacterial efficiency after ... 187
" list of ... 193
Wash water ... 181
see New York Filter Manufacturing Company, Morrison-Jewell Filtration Company, *see also* Mechanical Filters.
Johnstown, Pa., rainfall at ... 92
Jones Mills, on Indian Creek water-shed ... 90
Kansas City, use of meters in ... 77
Kiskiminetis River as a gravity source ... 80
Kittanning, analyses of samples from ... 321
Knabe's well, analyses of samples from ... 320
Knowles, Morris, C. E., reference to ... 2, 7, 38
" " " report of ... 107
Koch's plate culture method, reference to ... 334
Kuichling, Emil, C. E., reference to ... 6, 8, 29
" " " report on Indian Creek gravity supply by ... 87
Laboratory, biological, reference to ... 110, 114
" chemical, " ... 109
" cost of equipping ... 361
" Herron Hill, reference to ... 109
" of Bureau of Health ... 110, 327, 333
Land, estimated cost of, for filter sites ... 65
Larimer Ave., analysis of tap water from ... 319
" " " spring " ... 319
Laurel Hill Creek:—
Analyses of samples from ... 323
Annual charges ... 105
As a gravity supply ... 80
Cost of work ... 82, 93, 102
Dam, location of ... 93
Description of work required ... 93
Drainage area and capacity of ... 93
Quantity of water ... 81
Reference to ... 89
Tunnel from ... 93
Laurel Hill Ridge, reference to ... 89
Lawrence, Mass., filter at, reference to loss of head ... 47
" reference to open filters at ... 44
" typhoid fever in ... 20
" use of meters in ... 77
" visit to ... 2
Leffmann, Henry, reference to ... 227
Lettuce as a source of typhoid fever ... 12

PAGE.
Ligonier, reference to 80
Lime, *see* Alkalinity, Calcium carbonate and Hardness.
Lock No. 4, Monongahela River, rainfall at 92
Logwood, used in determining alumina 231
London, England, filters at, reference to loss of head 47
" " visit to 3
Loomis-Manning Filter Company, invitation sent to 111
Loss of head, reference to limit of 47
see also Jewell, Sand, Warren, and Worms Tile Filters.
Loss on ignition, method of determining 229
" " in samples 237
Louisville, Ky., report upon experiments at, reference to 50, 54, 58, 70
" " visit to 2
Lowell, Mass., typhoid fever in 20
" " use of meters in 77
Lycippus, Pa., rainfall at 92
Madison, use of meters in 77
Maintenance, cost of experiments 361
" estimated cost of; filters 66
" estimated cost of; gravity supply 103
Manchester, use of meters in 77
Manganous sulphate used in determining dissolved oxygen 232
Manning, Loomis-Manning Filter Company, reference to 111
Manufactories, drinking water in 71
Manufacturing, supply of water, *see* Auxiliary supply.
" use of water 71, 75
Maps, list of ..... ix.
Masonry, *see* Costs of filters, *see also*, Indian and Laurel Hill Creeks.
Massachusetts State Board of Health, reference to reports of 335, 336
McConway, Wm., reference to 1, 2
McConway-Torley Manufacturing Company, analyses of samples from well at 317
Mechanical analyses of sand, *see* Jewell, Sand and Warren Filters.
Mechanical Filters:—
Absorption of sulphate of alumina 54, 58
Action of sulphate of alumina 56
Alkalinity required, for sulphate of alumina 57
Alumina, *see* Sulphate of alumina.
Bacterial efficiency, after washing 49
" " compared with sand filters 60
" " highest, which can be obtained at Pittsburgh 59
" " influence of sulphate of alumina upon 50
" " " " turbidity upon 52
" " monthly averages 40
" " quantity of sulphate of alumina required to produce 56
Boiler use of effluent, compared to sand filters 63
Calcium carbonate required for sulphate of alumina 57, 59
Clarification, amount of sulphate of alumina required for 55
Clearness of effluents 61
Coagulants other than sulphate of alumina 76
Coagulant, *see* Sulphate of alumina.
Color of effluents 62

Mechanical Filters,—*Con.*:— PAGE.
Comparison with sand filters ... 60, 63, 68
Composition of water before and after filtration ... 43
Cost of sulphate of alumina ... 67
" " construction ... 64
" " effected by patents ... 65
" " maintenance ... 66
Depreciation ... 67
Efficiency, *see* Bacterial efficiency.
Effluents compared with those of sand filters ... 60
" waste of, after washing ... 49
Estimated cost of ... 65, 66
Hardness of effluent ... 62
Installation invited ... 110
Life of ... 67
Lime, *see* Calcium carbonate.
Maintenance, cost of ... 66
Muddy waters, *see* Turbidity.
Patents, effect of, upon cost ... 65
Quantities of water and rates of filtration ... 40, 41
Results with, classified ... 48
Sensitiveness to application of sulphate of alumina ... 61
Soda ash, use of in connection with sulphate of alumina ... 59
Storage reservoir for raw water, necessity of ... 68
Sulphate of alumina, absorption of ... 54, 58
" " " action of ... 56
" " " alkalinity required ... 57
" " " amounts used and required ... 40, 43, 55, 56
" " " average results with various quantities ... 54
" " " bacterial efficiency, influence on ... 50
" " " calcium carbonate required ... 57, 59
" " " cost of ... 67
" " " safe amount to use ... 56
Summary of results by months ... 40
Turbidity, absorption of sulphate of alumina caused by ... 54, 58
" influence of, upon bacterial efficiency ... 52
Wash water used and waste ... 40, 41
Washing, bacterial efficiency after ... 49
Waste ... 41, 49
Water quantities, monthly averages ... 41
see also Jewell and Warren Filters.
Mechanical filter companies, invitations sent to ... 111
see also Filter companies, Cumberland Manufacturing Company, Morrison-Jewell Filtration Company, and New York Filter Manufacturing Company.
Media, reaction of ... 339
Members of Commission, list of ... 8
Merrimac River compared to the Allegheny River ... 20, 23
Meters, trouble with air in ... 118
" use of, at Pittsburgh, recommended ... 73
" " " " report of Commission on ... 7

PAGE.
Meter rates, equitable basis for ... 77
Meter system, adoption of, for Pittsburgh ... 73
" " cities which have adopted ... 76
" " cost of installing ... 78
" " regulations for ... 76
Methods of bacterial examination ... 334
" " chemical analyses ... 225
" " filtration investigated ... 28
Metropolitan Water Board, reference to chief engineer of ... 92
Micro-organisms, cost of work upon ... 361
" defined ... 333
" report upon ... 349
Microscopical investigations ... 331, 349
Milk supply, as a source of typhoid fever ... 14
" " reference to ... 3
Mill Run, analyses of samples from ... 322
" " on Indian Creek water-shed ... 90
Mill supply of drinking water, as a source of typhoid fever ... 23
" " " water, *see* Auxiliary supply, *also* Manufacturing use.
Millvale, analyses of samples from ... 305
" crib, description of ... 306
" tap water, analyses of samples of ... 309
Milwaukee, use of meters in ... 77
Mine waste, effect of, on sand filters ... 45
Mineral analysis of Allegheny River ... 243
" " " Monongahela River ... 274
Miscellaneous city samples, analyses of ... 318
Miscellaneous studies ... 113
" " cost of ... 361
Miscellaneous suburban samples, analyses of ... 320
Monongahela River, analyses of samples from ... 270, 312
" " Beck's Run, analyses of samples from ... 319
" " character of ... 232
" " character of water supply drawn from ... 31
" " composition of, water ... 33
" " intake of Monongahela Water Company ... 270
" " list of cities and towns upon ... 32
" " Lock No. 4, rainfall at ... 92
" " mineral analysis of ... 274
" " sanitary condition of water drawn from ... 31
" " Turtle Creek, analyses of samples from ... 319
Monongahela Water Company, intake of ... 270
" " " reference to ... 16, 32, 79
Monthly results, summary of ... 39
see also Jewell, Sand, Warren, and Worms Tile Filters.
Montrose, analyses of samples from ... 278
" crib, description of ... 278
" effluent from crib, analyses of ... 280
see also Allegheny City water works.

PAGE.
Morrison-Jewell Filtration Company, reference to 111
see also Jewell and Mechanical Filters, *also* New York Filter Manufacturing Company.
Mortality, *see* Deaths.
Mount Vernon, filter at, reference to loss of head of 47
Mud, effect of, on sand filters 45
Muddiness of Allegheny River, how effected by storage 68
" " " " reference to 34
Nashville, Tenn., use of meters in 77
Natural gas, *see* Gas.
Natural sand filtration, through cribs or galleries 70
see also Sand filtration and Sand filters.
Nature of filtration 36
Negley Run spring, analyses of samples from 319
Negotiations with filter companies 111
Nessler's, reagent and tubes 226
New York City, reference to Cornell Dam 81, 97
" " typhoid fever, death rate in 11
" " use of meters in 77
New York Filter Manufacturing Company, invitations sent to 111
" " " " reference to purchase of Warren and Jewell Filters 65, 111
Nitrates, nitrogen as, method of determining 228
" " " in samples 237
Nitrites, " " method of determining 227
" " " in samples 237
Nitrogen, *see* Ammonia, Nitrates, Nitrites.
Observations, list of 116
Observers, list of 117
Odors due to micro-organisms 350
" in samples of water 225
Ohio River, at Sewickley, analyses of samples from 310
" reference to, *see* Louisville, Ky.
Oil City, distance from, and time of flow from, to Pittsburgh 19
Oil Well Supply Company, reference to 115, 226
Open filters, effect of winter on 44, 60
Operation, cost of experiments 361
see Jewell, Sand, Warren, and Worms Tile Filters.
Organic matter, in river water 233
see Ammonia, Nitrates, and Nitrites, *see also* Micro-organisms.
Organisms, *see* Micro-organisms.
Organization of Commission 1
" of force 109
Orifice indicators, used with sand filters 118
Oscillaria, found in samples 344, 352
Other Sources of Supply, Committee on 2
" " report of Commission on, reference to 29
see Gravity sources.
Over-flow, *see* Sand filters.

PAGE.
Oxidation, reference to 233
Oxide of iron, *see* Iron oxide.
Oxygen, dissolved, in effluents from sand filter 123
see also Dissolved oxygen.
Oysters, as a source of typhoid fever 12
Parietti's solution 327
Paris, visit to 3
Patents, on mechanical filters 5
" " " " effect of, on cost 65
Pawtucket, use of meters in 77
Pennsylvania, Department of Internal Affairs, records of 91
Perchloride of iron 202
Periods, between scrapings 47
Permanganate, *see* Caustic permanganate.
Permanency of filters, *see* Depreciation.
see also Life of filters.
Peoria, use of meters in 77
Petri dishes 335
see also Plates.
Petroleum, effect of, on sand filters 45
Phenolphthalein, used as an indicator 334,340
Pike Run, analyses of samples from 323
Pipe, Pipe lines, *see* Conduit, *also* Indian Creek, conduit.
Pitcairn, Robt., reference to 1
Pittsburgh, city tap water, analyses of 244
" Meter Company, reference to 158
Plants, list of, found in samples 352
Plates, artificial sandstone, *see* Worms Tile Filter.
" list of ..... ix.
" number of days allowed to develop 238, 239
" used in bacterial experiments 335
" *see also* Petri dishes.
Plating, method of 335
Police census of Pittsburgh, reference to 22
Pollution investigations of rivers and water-sheds 3, 114
Population of Pittsburgh, ... 27
" " now supplied by city water works 174
" " study of increase of 113
" " tabulation of, 1883-1900 ..... 73, 74
" " within 10 miles of City Hall 74
Potassium chromate, used in determining chlorine 228
" sulphocyanate used in determining iron, ... 231
Poughkeepsie, filters at, reference to loss of head of 47
" reference to open filters 44
Precipitate formed from solution of sulphate of alumina 56
Precipitation at Pittsburgh, ... 35
" near Indian Creek water-shed 92
Preliminary examination of samples 225
Present water supply, character of 3, 30
Pressure regulator 115, 158

PAGE.
Prodigiosus, Bacillus, application of ... 345
Proteus group ... 328
Protozoa, found in samples ... 350, 352
Providence, use of meters in ... 77
Public health, character of present water supply in relation to ... 3
Public Safety Department, laboratory of Bureau of Health ... 110, 327, 333
" " " tap in building of, analyses of samples from ... 312
Public water supply, as a source of typhoid fever ... 14
" " " for institutions and meter system ... 76
" " " use of water from ... 75
Public Works, Director of, reference to ... 3, 109, 111
Pumps, *see* Jewell and Warren Filters.
Pumping machinery, depreciation of ... 66, 83
" " pump house, estimated cost of ... 65
Pumping station, *see* Auxiliary supply.
" *also* Filter estimates.
Purification, self, of streams ... 17
Quality of water, *see* Bacteria, *see* Water.
" *also* Indian Creek and Laurel Hill Creek.
" " Jewell, Sand, Warren, and Worms Tile Filters.
Quantity of water required, *see* Water, quantity required.
Quantity passed, *see* Jewell, Sand, Warren, and Worms Tile Filters.
Quincy, use of meters in ... 77
Quiescence, as a factor in self-purification of streams ... 17
Rainfall at Pittsburgh ... 35
" various places near Indian Creek water-shed ... 92
see also Precipitation.
Rains, effect of, on rivers ... 232
Rakes, *see* Jewell and Warren Filters.
Rapidity of streams as a factor in self-purification ... 18
Rates, equitable basis of, for meter system ... 77
" of filtration, *see* Jewell, Sand, Warren, and Worms Tile Filters.
" of flow, *see* Allegheny River.
" *also* Jewell, Sand, Warren, and Worms Tile Filters.
Raw water, bacteria in, monthly averages ... 39
Reaction of media ... 339
Recommendations of Commission ... 7
" " Consulting Engineer ... 85
Reducing pressure valve ... 115, 158
Red Wing, Minn., sand from ... 180
Regulator, for thermostat ... 337
" pressure, on main water line ... 115, 158
see Jewell and Warren Filters.
Renewals, charges for, *see* Costs, Depreciation, Estimates.
Report of Commission ... 1
Reports, list of ... 7
Representatives of filter companies ... 111
Reservoir, estimated cost of ... 65
" species of bacteria found in ... 346
" storage, for raw water ... 68
see also Gravity Supply, Indian Creek and Squaw Run.

PAGE.
Resident Engineer, reference to 2, 7, 38
Resident Engineer's Report 107
" " " reference to 7, 38
Residue on evaporation, method of determining 229
" " " in samples 237
Resler's Run, analyses of samples from 323
" " reference to 89, 190
Resolution creating Commission iii
Restriction in waste of water 73
Results with experimental filters 38
Riddle, Dr. Walther, reference to 2, 38, 109, 116
" " report of 223
River sands, analyses of 121
River water, bacteria in and turbidity of, monthly averages 38
" " used in mills 23
see also Allegheny River, Monongahela River, *also* Auxiliary supply.
Rivers, *see* Allegheny, Monongahela and Youghiogheny, *also* Indian Creek.
River pollution, reference to 3, 17, 114
Rivers Pollution Commission, reference to 17
Safety, Department of Public, laboratory of Bureau of Health 110, 327, 333
Salaries, amount of 361
Salt Lick Township on Indian Creek water-shed, population of 90
Samples, chemical analyses of 237
" how collected 225
Samples of Pittsburgh city water, bacteriological investigations of 325
Sand, *see* Jewell, Sand, and Warren Filters.
Sand, depth of, removed by scraping 47
Sand Filters:—
Advisability of establishing 4
Analyses of samples from 246
Analyses of sand 121, 122
Area of experimental 118
Asbestos, use of, with 70
Ammonia in sand 122
Auxiliary supply, saving in cost of, by establishing 72
Bacteria, in effluents 39, 127
" " species of 345
" in sand 122
" in underdrains, growth of 60
" large numbers in effluent 120
Bacterial efficiency 39, 127
" " after scraping 123
" " compared with mechanical filters 60
Batter of walls 118
Boilers, use of effluents from, in 63
Calcium carbonate in sand 62, 122
Capacity of settling basin 117
Chemical analyses of samples 246
Clearness of effluents 61
Color of effluents 62
Comparison with mechanical filters 60, 63, 67

Sand Filters,—*Con.:*— PAGE.
Composition of river water before and after passing 39
Construction, cost of 64
Construction of experimental, decided upon 110
Cost of construction 64
Cost of experimental 361
" maintenance 66
Covering, necessity of 44
Cracks in filter walls 120
Daily results 127
Dates of operation 119
Depth of sand removed by scraping 47
Description 117
Dissolved oxygen 123
Effect of 3
" mud, petroleum and mine waste upon 45
" winter on 60
Effective size of sand 122
Efficiency, *see* Bacterial efficiency.
Effluent pipes 118
Effluents, analyses of 253
" compared with those from mechanical filters 60
Elevation 118
Estimate of cost 65, 66
Experiments with, cost of 361
Freezing of surface, effect of 120
Frequency of scraping 47
Growth of bacteria in underdrains 60
Hardness of effluents 62
Indicators, reference to 118
Leaks through filter walls 120
Leveling on surface 121
Lime in sand, *see* Calcium carbonate.
Loss of head 47, 120, 127
Location of experimental 114
Maintenance, estimated cost of 66
" of experimental, cost of 361
Mechanical analyses of sand 121
Meters used with experimental 118
Methods used with experimental 120
Micro-organisms found in effluents 349, 354, 355
Monthly results 126
Net yield from, monthly averages 39
Operations 119
Organic matter in sand 122
Orifice indicators 118
Overflows 118
Oxygen, dissolved 123
Periods of operation 119
" " between scrapings 47
Plan 118

Sand Filters,—*Con.*:— PAGE.
Quantities between scrapings 47
" filtered 127
Rates of filtration 39, 119, 123, 127
Reference to experiments with 110
Repairs to experimental 120
Results, tabulation of 126
" with, classified 44
River sands, analyses of 121
Samples from, analyses of 246
Sand, analyses of 121, 122
" area of 118
" bacteria in 122
" elevations of 118
" freezing of 120
" removed by scraping 118, 127
" size of 121, 122
" tamped 121
Scraping, bacterial efficiency after 123
" frequency of, and periods between 47
" list of 127
" rate of filtration after 123
Section 118
Sedimentation, necessity for preliminary 44
Settling basin, description of 117
Settled water, analyses of 250
Species of bacteria found in effluents from 345
Storage reservoir for raw water, necessity for 68
Summary of results with, by months 39
Tabulation of results 126
Tamping of sand 121
Time in operation 127
Turbidity, records of 127
Underdrains, description of 118
" growth of bacteria in 60
Walls, cracks in 120
Sandstone tiles, *see* Worms Tile Filters.
Sand washing, *see* Jewell and Warren Filters.
San Francisco, use of meters in 77
Sanitary condition of present water supply 3, 30
Sanitary studies, cost of 361
see also Pollution investigations.
Scale, *see* Boilers, experimental.
Schenley Park tap, bacterial examination of samples from 330
Scope of investigations 1
Scraping, *see* Sand filters.
Screens, *see* Jewell and Warren Filters.
Secondary infection 3
Secretary of Commission 1
Sedgwick, Prof. W. T., reference to 7, 27
" " " report of 9

PAGE.
Sedgwick, Prof. W. T., studies made for ... 113
Sedgwick-Rafter method, reference to ... 349
Sediment in samples of water ... 225
Sedimentation, necessity of preliminary, for sand filters ... 44
Sedimentation basins, can be built over into filters ... 69
" " " estimated cost of ... 65
Seger's well, analyses of water from ... 320
Self-purification of streams ... 17
Sensitiveness of mechanical filters to application of sulphate of alumina ... 61
Serial numbers of samples ... 237
Services, how to be metered ... 76
Service pipes to be overhauled ... 78
Settled water, sand filters, analyses of samples from ... 250
" " " bacteria in, and composition of, monthly averages ... 39
Settling, necessity of, with sand filtration ... 44
Settling basin, analyses of samples from ... 250
" estimated cost of ... 65
see also Sedimentation basins, *also* Jewell, Mechanical, Sand, Warren, and Worms Tile Filters.
Sewage pollution, *see* Pollution investigations.
Sewickley, analyses of samples from ... 310, 311
" crib, description of ... 310
Shafts, *see* Indian Creek, tunnel, *also* Tunnel shafts.
Sharpsburg crib, analyses of samples from ... 298
Shepherd, A. B., reference to report of ... 109
" " report of, on Driven Well Supply ... 360
Shetland Ave., analyses of tap water from ... 319
Silver nitrate, used in determining chlorine ... 228
Simplicity of operation of filters ... 5
Sinking fund charges, on cost of filtration ... 66
" " on cost of gravity supply ... 83, 104
Sinks, coal, *see* Indian Creek, conduit
Size of sand, *see* Effective size; *see also* Sand filters.
Sligo Mills, analyses of samples from well at ... 318
Slow sand filters, *see* Sand filters.
Smith, Frank B., reference to ... 116
" Theobald, reference to ... 327
Soap solution, reference to ... 230
Soda ash, use of, in connection with sulphate of alumina ... 59
Sodium hydrate, used in determining dissolved oxygen ... 232
" " " " nitrates ... 228
Sodium thiosulphate, used in determining dissolved oxygen ... 232
Solids, in samples ... 237
" method of determining ... 229
Somerset, Pa., rainfall at ... 92
Sources of samples ... 237
Sources of Supply, Other, Committee on ... 2
" " " reference to ... 29
" " " report of Commission on ... 6
Sources of typhoid fever, classification of ... 12
South Side, character of water supplied to ... 31

PAGE.
South Side, supply of, with filtered water..... 79
" typhoid fever upon..... 16
see also Monongahela River.
South Side reservoir, micro-organisms found in samples from..... 358
" tap, analyses of samples from..... 275
" tap, bacterial examination of samples from..... 330
Special samples, from Allegheny River..... 243
" " gate chamber..... 249
Species of bacteria..... 344
" work, cost of..... 361
Spillways, *see* Indian Creek, conduit.
Spirogyra, found in samples..... 349, 352
Spree River, reference to..... 28
Spring waters, analyses of..... 319, 320
" as a source of typhoid fever..... 23
Springfield, on Indian Creek water-shed, population of..... 89, 96
" " " reference to..... 90
" Mass., use of meters in..... 77
Springs, reference to waters from..... 3
Squaw Run, survey of..... 112
see also Sand filters, storage reservoir for raw water; *also* Storage basin.
St. Louis, Wormser Filter Plate Company of, reference to..... 112
Stearns, F. P., reference to water-shed table of..... 93
Steel pipe conduits, coefficient of..... 100
" " roughness of inside surface of..... 100
see also Indian Creek.
Sterilization of media..... 335
Stigeoclonium, found in samples..... 349, 352
Still, ammonia..... 226
Storage reservoir for raw river water, estimated cost of..... 65
" " " necessity for..... 68
Stoyestown, Pa., rainfall at..... 92
Studies, miscellaneous..... 112
see also Investigations.
Subsidence over coal workings, *see* Indian Creek.
Suburban samples, analyses of miscellaneous..... 320
Sudbury River, rainfall on water-shed..... 92
Sulphate of alumnia, absorption of, by muddy waters..... 54, 58
" " action of and safe amount to use..... 56
" " estimated cost of..... 66, 67
see also Coagulant, *also* Jewell, Mechanical, and Warren Filters.
Sulphuric acid, in Monongahela River..... 233
" " in samples..... 237
" " method of determining..... 230
Summary, *see* Conclusions.
Superintendent, to meter services..... 76
Superintendent of Bureau of Water Supply and Distribution, report by..... 360
Supply, Other Sources of, Committee on..... 2
see also Gravity supply, *also* Water supply.

PAGE.
Surveys, of filter sites, reference to 112
see Indian Creek.
Suspended matter, absorption of sulphate of alumina, with different amounts of. 58
" " in samples 237
" " method of determining 229
Syracuse, use of meters in 77
Systems, *see* Distribution system, *also* Meter system.
" of filtration, *see* Filters, *also* Filtration.
Tanks, effluent 115
see also Worms Tile Filter.
Taps, analyses of samples from, in Pittsburgh 319
" bacterial examination of samples from 330
" in Department of Public Safety Building, analyses of water from 312
" species of bacteria found in 346
see also Allegheny, Etna, Millvale, Pittsburgh, Sewickley, Sharpsburg, South Side, Verona, and Wilkinsburg.
Taste in waters, *see* Odors.
Taunton, use of meters in 77
Temperature, appliances used to control, in thermostat 337
" at Pittsburgh 36
" average of thermostat 336
" development of plates, effected by 338
" effect of, on open filters at Pittsburgh 44
" thermostat, by months 336, 342
" used in bacterial examinations 336
Temporary hardness, *see* Alkalinity, *also* Hardness.
Tests for Bacillus *coli communis* 348
Thames River, reference to 28
Theory of filtration 36
Thermal death point 347
Thermostat, temperature in 336, 342
" temperature, regulator for 337
Thick waters, reference to 52
Thiocyanate, used in determining iron 231
Thompson's Run, analyses of water from 320
Thompson Street, analyses of tap water from 319
Tiles, *see* Worms Tile Filter.
Toledo, use of meters in 77
Total hardness, *see* Hardness.
" solids, *see* Solids.
" *also* Residue on evaporation.
Towns on water-sheds, *see* Allegheny and Monongahela Rivers, *also* Indian Creek.
Toy, Wm., reference to 117
Trailing, *see* Jewell Filter.
Tunnel under Allegheny River, estimated cost of 65
" *see* Indian Creek, tunnel; *also* Laurel Hill Creek, tunnel.
Turbidity, absorption of sulphate of alumina by 54
" classified 53, 225
" daily observations, *see* Jewell, Sand, Warren, and Worms Tile Filters.
" effect of, on sand filters 45

PAGE.
Turbidity, effect of, on mechanical filters..... 52
" how observed..... 34, 68, 225
" of samples..... 237
" of mountain streams, of gravity supplies..... 80
" of river water, monthly averages..... 39
" of river water, summary of observations..... 35
" storage, effect of, upon..... 68
Turtle Creek, analyses of samples from..... 320
Twenty-first ward, analyses of samples from..... 318
" " typhoid fever in..... 113
Typhoid Fever:—
Contagion of..... 13
Deaths in Pittsburgh from..... 11
Diagrams showing distribution of..... 22, 24
Distribution of, in Pittsburgh..... 22
Epidemic of, traced to milk supply..... 14
Germs, difficulty of detecting..... 21
Ice supply, as a source of..... 14
Infection, secondary..... 3, 13
Milk supply, as a source of..... 14
Monongahela River water, as a source of..... 15
Report upon sources of..... 9
Secondary infection..... 3, 13
South Side, amount of, upon..... 16
Studies of..... 113
Water supply, as a source of..... 14
Ulothrix, found in samples..... 349, 352
Underdrains, growth of bacteria in..... 60
" of sand filters..... 118
Unfiltered supply of water, *see* Auxiliary supply.
Uniformity coefficient of sand, *see* Jewell, Sand, and Warren Filters.
Uniontown, Pa., rainfall at..... 92
United States Engineers, reference to..... 19
" " Weather Bureau, rainfall records from..... 92
Utica, use of meters in..... 77
Valves, *see* Indian Creek, valves.
" *also* Reducing pressure valve.
Vegetables as a source of typhoid fever..... 12
Vehicles of typhoid fever..... 12
Velocity of Allegheny River..... 19
Verona tap, analyses of samples from..... 289
see also Hulton.
Vice-chairman of Commission..... 1
Visits to experimental filter plant..... 116
" " other cities..... 2, 116
Wages, amount of..... 316
Warren Filter:—
Agitator..... 158
Air needed to supply weir..... 158
Alkalinity of effluent..... 161
Alumina, *see* Sulphate of alumina.

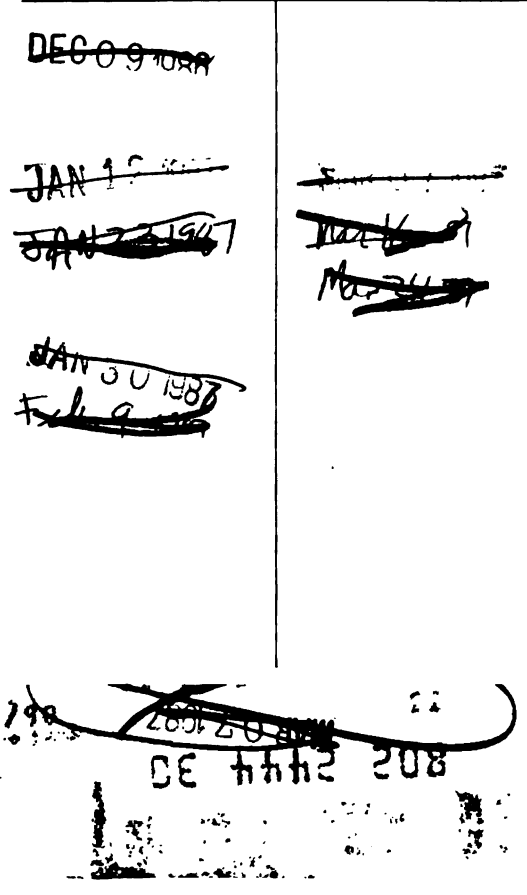
Warren Filter,—*Con.*:— PAGE.
Analyses, bacterial ... 171
" chemical ... 260
" of sand used ... 157
Application of coagulant ... 155
" " " variation in ... 160
Area of exit openings ... 157
" " sand ... 156
Automatic weir ... 155, 157
Bacteria in effluent ... 160, 171
" " " after washing ... 166
" " " no coagulant used ... 170
" " raw water ... 160, 171
" " settled water ... 171
Bacterial efficiency after washing ... 166
" " with different amounts of coagulant ... 170
Baffle walls ... 155
Brass strainer floor ... 156
Butterfly valve ... 155
Calcium carbonate, *see* Alkalinity.
Chemical analyses of effluent ... 260
Coagulant, application of ... 155
" " " variation in ... 160
" composition of ... 159
" effect of using different quantities of ... 169
" pumps and tubs ... 156
Cost of experiments with ... 361
Daily results ... 171
Description ... 155, 156
Depth of sand ... 157
Efficiency, *see* Bacterial efficiency.
Effluent, alkalinity of ... 161
" analyses of samples of ... 260
" bacteria in, after washing ... 166
" micro-organisms found in ... 355
Engine, power from ... 158
Error in meters ... 158
Exit area ... 157
Experiments with, cost of ... 361
Filtration, variation in rate of ... 160
Flap valve ... 155
Float in settling basin ... 155
" weir ... 157
Floor, strainer ... 156
Gutters ... 157
Hours in operation ... 171
Leaks from tanks ... 158
Lift, hydraulic ... 158
Micro-organisms found in effluent ... 355
Meters ... 155
" error in, caused by air ... 158
Monthly results, tabulation of ... 40, 171

Warren Filter,—*Con.*:— PAGE.
Operations ... 159
Orifice ring in weir ... 157
Power used in washing ... 158
Pressure valve, reducing ... 158
Propeller ... 155
Pump, coagulant ... 156
Quantities filtered ... 171
Quartz used ... 157
Rakes ... 158
Rate of filtration, variation in ... 160
Records of operations ... 159
Regulator, pressure ... 158
Results by months, tabulated ... 40, 171
Ring, orifice, in weir ... 157, 160
Rubber valves ... 156
Samples, analyses of ... 260
Sand, analyses of ... 157
" area of ... 156
" depth of ... 157
Screens, brass ... 157
Section ... 156
Settled water, analyses of samples of ... 262
Settling basin, description of ... 155
Special experiments ... 160, 169
Sulphate of alumina, analyses of ... 159
" " quantities used ... 160, 172
Summary of results ... 40
Surface, area of ... 156
Tests, special ... 160
Time in operation ... 172
Troughs ... 157
Turbidity of effluents ... 171
Tympanum ... 156
Valve, butterfly and flap ... 155
" reducing pressure ... 158
" rubber ... 156
Variations in rate of filtration and the application of coagulant ... 160
Washing, description of ... 157
" effect of ... 166
" list of ... 172
Weir, automatic ... 155, 157
Well, central ... 157
see also Cumberland Manufacturing Company, Mechanical Filters, and New York Filter Manufacturing Company.
Wasdin, Dr. Eugene, reference to ... 120
" " report of ... 325
" " table of results secured ... 330
Washing, Wash water, *see* Jewell, Mechanical, and Warren Filters.
Wash water pumps ... 115
Washington County, Lock No. 4, rainfall in ... 92

PAGE.
Waste of water in Pittsburgh..... 73, 95
" water, *see* Jewell, Mechanical, and Warren Filters.
" weir, *see* Indian Creek, conduit.
Wasting effluents..... 49
see also Jewell, Mechanical, and Warren Filters.
Water Analysis, Committee on..... 1
" borne diseases..... 8
see also Typhoid fever.
" domestic, use of..... 47
" manufacturing use of..... 71, 75
" public use of..... 75
" sheds, inspection of..... 3
see also Allegheny and Monongahela Rivers, Gravity sources, Indian and Laurel Hill Creeks.
" supply, as a source of typhoid fever..... 14
" " Bureau of, and Distribution, money expended by..... 361
" " character of present..... 3
" " gravity, reference to..... 6, 29, 80
see also Allegheny and Monongahela Rivers, Gravity sources, Indian Creek, and South Side.
" to be provided and restriction of waste..... 73, 74, 93
Weather Bureau, records of rainfall..... 92
Weirs, automatic, *see* Warren Filter.
" waste, *see* Indian Creek, conduit.
Wells, analyses of samples from..... 319, 320
" supply of water from..... 3
see also Driven well, McConway-Torley Manufacturing Company, Sligo Mills.
Western University of Pennsylvania, students of, employed..... 114
" Water Company, communication from..... 113
" " " property rights on Indian Creek..... 81
Westmoreland County, Pa., rainfall in..... 92
" " " reference to, on Indian Creek water-shed..... 90
West Newton, Pa., rainfall at..... 92
White Run, reference to, end of Indian Creek tunnel..... 98
Widal-Pfeiffer, blood test, reference to..... 327
Wildwood, analyses of samples from..... 292
" crib, description of..... 292
" " analyses of samples from..... 294
" *see also* Wilkinsburg.
Wilkins & Davison, reference to survey by..... 113
Wilkinsburg Reservoir, asterionella found in..... 351
" " micro-organisms found in..... 358
" tap, analyses of samples from..... 296
see also Wildwood.
Winter, effect upon sand filters..... 44, 60, 120
Worcester, use of meters in..... 77
Worms Tile Filter:—
Analyses of samples from..... 265
Artificial sandstone tiles..... 203
Bacteria, daily results..... 207

Worms Tile Filter,—*Con.*:— PAGE.
Bacterial efficiency ... 205
Breakage of tiles ... 204
Chloride of iron ... 202
Clogging of tiles ... 205
Coagulant ... 202
Composition of tiles ... 203
Cost of experiments with ... 361
Daily results ... 207
Description ... 202
Effluents, analyses of ... 268
" bacteria in, after washing ... 205
Elevation ... 204
Estimated cost ... 70
Experiments, cost of, with ... 361
Ferric chloride ... 202
Hours in operation ... 212
Indicators ... 203
Iron ore used ... 212
" solution ... 202
Loss of head ... 204
Monthly results ... 207
Negotiations in regard to ... 112
Opalescence of effluents ... 203
Operations ... 204
" hours in ... 212
Orifice indicator ... 203
Place of manufacture ... 203
Plan ... 204
Quantities filtered, and, of wash water ... 212
Rate of flow ... 204
Reference ... 69
Results, tabulation of ... 207
Samples, analyses of ... 265
Scrubbers ... 202
Section ... 204
Settled water, analyses of ... 266
Tanks and tiles ... 203
Turbidity, records of ... 212
Washing, bacterial efficiency after ... 205
" list of ... 212
" method of ... 203
Wash water, amount of ... 204
Worms, Germany, reference to filters used at ... 111
Wormser Filter Plate Company, reference to ... 111
Wurtz litmus agar ... 328
Yield of filters, *see* Jewell, Mechanical, Sand, Warren, and Worms Tile Filters.
Yonkers, use of meters in ... 77
Youghiogheny River, analyses of samples from ... 324
" " as a gravity source of supply ... 80

This book should be returned to the Library on or before the last date stamped below.

A fine is incurred by retaining it beyond the specified time.

Please return promptly.